III. *Concluſion of the Experiments and Obſervations concerning the Attractive Powers of the Mineral Acids. By* Richard Kirwan, *Eſq. F. R. S.*

Read Dec. 12, 1782.

HAVING found, as exactly as I was able, the quantity of each of the mineral acids taken up at the point of ſaturation by alkalies and earths, and alſo that taken up by phlogiſton, when theſe acids are by it converted into an aërial form, I next endeavoured to find how much of theſe acids was taken up at the point of ſaturation by each of the metallic ſubſtances, and for this purpoſe procured the moſt ſaturated ſolution poſſible of each metallic ſubſtance ſoluble in any of theſe acids. Theſe ſolutions did not, indeed, immediately anſwer my purpoſe, as they conſtantly retained an exceſs of acid; yet as they were the foundation of my ſubſequent obſervations, and as the experiments themſelves are in many reſpects uſeful to be known, I ſhall here briefly relate their reſult, and confine myſelf to thoſe circumſtances ſingly that relate to my future inveſtigations, or that have not heretofore been ſatisfactorily explained. The acids I uſed were dephlogiſticated ſo far as to be colourleſs; the metals were for the moſt part very fine filings, or reduced in a mortar to a fine powder. They were added little by little to their reſpective menſtruums, much more being thus diſſolved than if the whole was thrown in at once; and the ſolution was performed in glaſs phials with bent tubes.

Solution of iron in the vitriolic acid.

100 grs. of bar-iron, in the temperature of 56°, require for their ſolution, 190 grs. of real acid, whoſe proportion to that of the water with which it ſhould be diluted, is as 1 to 8, 10, or 12. It would act on iron, though its proportion were greater or leſſer, but not ſo vigourouſly. If towards the end a heat of 200° were applied, 123 grs. of real acid would be ſufficient.

The air produced by this ſolution is intirely inflammable, and generally amounts to 155 cubic inches.

Iron is alſo ſoluble with the aſſiſtance of a ſtrong heat, and in ſmaller quantity in concentrated vitriolic acid; and in this caſe ſcarce any inflammable air is produced, but a large quantity of vitriolic air as Dr. PRIESTLEY has obſerved, and a ſmall quantity of ſulphur ſublimes at the latter end. This fact is a clear refutation of Mr. LAVOISIER's hypotheſis; for is it not evident, that the ſame ſubſtance which, when a dilute acid is uſed, goes off in the form of inflammable air, does when a concentrated acid is uſed, to unite this acid, and thus form both vitriolic air and ſulphur? In the firſt caſe it cannot unite to the acid, by reaſon of the large quantity of water combined with the acid; and as the liquor, being moſtly aqueous, contains a large quantity of ſpecific fire, it receives that fire when the acid unites to the metallic earth, and flies off in the form of air. But in the ſecond caſe, the concentrated acid, containing much leſs ſpecific fire, cannot expel the phlogiſton in the form of inflammable air (as this air abſorbs a vaſt quantity of fire) but unites to it, when by heat it is further ſtripped of its water, and thus forms both vitriolic air and ſulphur. 100 grs. of iron, diſſolved without heat, afford upwards of 400 of vitriol.

100 grs. of the vitriol cryſtallized contain 25 of iron, 20 of real acid, and 55 of water. When calcined nearly to redneſs theſe cryſtals loſe about 40 of water.

The calces of iron are more or leſs ſoluble in this acid according to their degree of dephlogiſtication. Thoſe that are phlogiſticated (as that recently precipitated from a ſolution of vitriol by fixed alkalies) are alſo moſt ſoluble, and upon evaporation afford cryſtals, though paler than thoſe formed of genuine iron. Thoſe that are leaſt phlogiſticated are alſo leaſt ſoluble, that is, require more real acid for their ſolution, and afford no cryſtals, but only a magma or mother liquor. Hence alſo, ſolutions of iron newly made diminiſh, and conſequently phlogiſticate the ſuper-incumbent air, and conſequently gradually emit phlogiſton: and hence the calx, being more dephlogiſticated, gradually falls unleſs more acid be added to keep it in ſolution.

Iron in the nitrous acid.

100 grs. of iron, to be perfectly diſſolved, and not barely calcined, require 142 grs. of real nitrous acid, ſo diluted as that its proportion to water ſhould be as 1 to 13 or 14; and when this laſt proportion is uſed, the heat of a candle may be applied for a few ſeconds, and the acceſs of common air prevented. In this caſe not above 18 cubic inches of nitrous air are produced, all the reſt is abſorbed by the ſolution, and no red vapours appear. But if the proportion of acid and water be as 1 to 8 or 10, and heat be applied, a much greater quantity of iron will be dephlogiſticated, though very little of it be held in ſolution; and by this means I have obtained from 100 grs. of iron, 83,87 cubic inches

of nitrous air; and by diſtilling the ſolution a ſtill greater quantity may be obtained, which was abſorbed by the ſolution. No inflammable air is obtained from ſolutions of iron or any other metallic ſubſtance in the nitrous acid, becauſe this acid has leſs affinity to water, and more to phlogiſton, than the vitriolic acid, and alſo contains much leſs fire than either the vitriolic or marine acids, as will be ſeen in the ſequel, and therefore unites to phlogiſton inſtead of barely expelling it. And hence it is, that the vitriolic acid, though united with 30 times its weight of water, will ſtill viſibly act on iron, and ſeparate inflammable air in the temperature of 55°; whereas nitrous acid, diluted with 15 times its weight of water, will have no viſible effect on iron in that temperature.

The calces of iron, if not too much dephlogiſticated, are alſo ſoluble, though difficultly, in the nitrous acid.

Iron in the marine acid.

100 grs. of iron require 215 of real marine acid for their ſolution. The proportion of acid to that of water in the ſpirit of ſalt I uſed was as 1 to 4. When it is as 1 to 4, it effervesces too violently. Heat is rather prejudicial, as it volatiliſes the acid. No marine air flies off, and the quantity of inflammable air is juſt the ſame as if dilute vitriolic acid were uſed.

The calces of iron are alſo ſoluble in marine acid. They may be diſtinguiſhed from genuine iron in this, that their colour, when precipitated by fixed alkalies, is *reddiſh*, whereas the precipitate of genuine iron is *greeniſh*.

Copper in the vitriolic acid.

100 grs. of copper require nearly 183 grs. real vitriolic acid for their ſolution. The proportion of acid to that of water

being as 1 to ½, or at leaſt as 1 to $\frac{7}{10}$, and a ſtrong heat muſt alſo be applied. I could never diſſolve the whole of any quantity of copper; but to diſſolve a given quantity of it, a ſtill greater muſt be uſed in the proportion of nearly 28 to 100, though this reſiduum alſo is ſoluble by adding more acid. When copper has been dephlogiſticated in this manner, a ſolution of it is obtained by adding warm water to the dephlogiſticated maſs.

The dephlogiſtication of 128 grs. of copper treated in this manner affords 11 cubic inches of inflammable air, and nearly 65 of vitriolic air. When I obtained inflammable the acid was a little more aqueous. The reaſon why copper cannot be dephlogiſticated by dilute vitriolic acid, nor even by the concentrated, without the aſſiſtance of a ſtrong heat, as iron is, appears deriveable from its much ſtronger attraction to phlogiſton, and the much greater quantity of it which copper contains, as will hereafter be ſeen. Hence

100 grs. of vitriol of copper contain 27 of copper, 30 of acid, and 43 of water, of which it loſes about 28 by evaporation or ſlight calcination.

The ſolution of 100 grs. of copper affords 373 of blue vitriol.

Copper in nitrous acid.

100 grs. of copper require 130 of real nitrous acid to diſſolve them. If the acid be ſo far diluted as that its proportion to that of water be as 1 to 14, the aſſiſtance of heat will be neceſſary, otherwiſe not. This ſolution affords 67½ cubic inches of nitrous air.

The calces of copper are alſo ſoluble in this acid.

Copper in marine acid.

100 grs. of copper require 1190 grs. of real marine acid to diſſolve them, and alſo the aſſiſtance of a moderate heat, the proportion of acid to that of water being as 1 to $4\frac{1}{3}$, that is, its ſpecific gravity being 1,186, if a greater heat be uſed, more of the acid will be requiſite, as much will be diſſipated. If the acid be more concentrated, it will act more vigorouſly.

In my laſt paper I mentioned, that $8\frac{1}{2}$ grs. of copper afforded 86 of marine air: however, I muſt now add a circumſtance which I then did not attend to, which is, that the mercury over which that air was received was acted upon, ſo that part of the air was due to this action, which invalidates the concluſion I there drew concerning the quantity of phlogiſton in marine air, which hence appears to be greater than I there eſtimated it.

The calces of copper are alſo ſoluble in this acid, though not ſo eaſily as in the nitrous acid.

Tin in the vitriolic acid.

100 grs. of tin require for their perfect ſolution 872 grs. of real vitriolic acid, whoſe proportion to water ſhould not be leſs than as 1 to $\frac{9}{10}$, and alſo the aſſiſtance of a ſtrong heat; when the action of the acid has ceaſed, ſome hot water ſhould be added to the turbid ſolution, and the whole again heated. This ſolution affords 70 cubic inches of inflammable air. Tin is alſo ſoluble in a more dilute acid, but not in ſo great quantity.

The calces of tin (except that precipitated from marine acid by fixed alkalies) are inſoluble in this acid.

Tin in the nitrous acid.

100 grs. of tin require, for their perfect ſolution, 1200 grs. of real nitrous acid, whoſe proportion to water ſhould be at leaſt as 1 to 25, and the heat not exceeding 60°: the quantity of air afforded by ſuch ſolution is only ten cubic inches, and it is not nitrous. The ſolution is not permanent; for in a few days it depoſits a whitiſh calx, and if the weather be warm burſts the phial. The calces of tin are inſoluble in this acid.

Tin in the marine acid.

100 grs. of tin require for their ſolution 413 of real marine acid, whoſe proportion to water is as 1 to $4\frac{1}{2}$, and alſo the aſſiſtance of a moderate heat. This ſolution affords about 90 cubic inches of inflammable air and 10 of marine air. The calces of tin are nearly inſoluble in this acid.

Lead in the vitriolic acid.

100 grs. of lead require for their ſolution 600 grs. of real acid, whoſe proportion to water is not leſs than that of 1 to $\frac{7}{10}$, and better if the quantity of water be ſtill leſs; and hence, as with regard to copper, a greater quantity of lead ſhould be employed than is expected to be diſſolved. A ſtrong heat is alſo requiſite, and hot water ſhould be added to the calcined maſs, though ſparingly, as it occaſions ſome precipitation.

This metal is alſo ſoluble, but in a very ſmall degree, in dilute vitriolic acid; for it efferveſces with ſpirit of vitriol whoſe ſpecific gravity is only 1,275.

The calces of lead are ſomething more ſoluble in this acid. 100 grs. of vitriol of lead, formed by precipitation, contains 73 of lead, 17 of real acid, and 10 of water. Vitriol of lead, formed by direct ſolution, contains a large proportion of acid.

Lead in the nitrous acid.

100 grs. of lead require for their ſolution about 78 grs. of real acid, whoſe proportion to that of water may be as 1 to 11 or 12, and the aſſiſtance of heat towards the end. This ſolution affords but eight cubic inches of nitrous air. The calces of lead are alſo ſoluble in this acid; but if much dephlogiſticated they become leſs ſoluble.

100 grs. of minium require 81 grs. of real acid.

100 grs. of nitrous ſalt of lead contain about 60 of lead.

Lead in the marine acid.

100 grs. of lead require 600 grs. of real acid to diſſolve them, when the ſpecific gravity of the ſpirit of ſalt is 1,141, and alſo the aſſiſtance of heat, by which much of the acid is diſſipated. A ſtronger acid would diſſolve more.

The calces of lead are more ſoluble in this acid than genuine lead. 100 grs. minium require 327 grs. of real acid; but white lead is much leſs ſoluble.

100 grs. of horn lead, formed by precipitation, contain 72 of lead, 18 of marine acid, and 10 of water.

Silver in the vitriolic acid.

100 grs. of pure ſilver require to diſſolve them 530 grs. of real vitriolic acid, whoſe proportion to water is not leſs than that of 1 to $\frac{8}{10}$, and when ſuch a concentrated acid is uſed, it acts ſlightly even in the temperature of 60°; but for a copious

ſolution a moderate heat is requiſite. This ſolution affords 30 cubic inches of vitriolic air. Standard ſilver affords more air and requires more acid for its ſolution. The calces of ſilver (that is, ſilver precipitated from its ſolution in nitrous acid by fixed alkalies, and well-waſhed, but which ſtill retains ſome nitrous acid), are ſoluble even in dilute vitriolic acid, without the aſſiſtance of heat. 100 grs. of vitriol of ſilver, formed by precipitation, contain 74 grs. of ſilver, about 17 of real acid, and 9 of water.

Silver in the nitrous acid.

100 grs. of the pureſt ſilver require for their ſolution 36 of mere nitrous acid, diluted with water in the proportion of one part real acid to 6 of water, applying heat only when the ſolution is almoſt ſaturate. If ſpirit of nitre be much more or much leſs dilute, it will not act without the aſſiſtance of heat. The laſt portions of ſilver, thus taken up, afford no air. *Standard* ſilver requires about 38 grs. of real acid to diſſolve the ſame proportion of it. And the ſolution of it affords 20 cubic inches of nitrous air, whereas 100 grs. of ſilver, revived from *luna cornua*, afford about 14.

Silver in the marine acid.

I have not been able to diſſolve ſilver, in its metallic ſtate, in ſpirit of ſalt, yet I believe it may be effected, if ſufficient time be allowed, as Mr. BAYEN, in his Treatiſe on Tin, p. 201. ſays, he diſſolved 3½ grs. of ſilver by digeſting it for ſome days in two ounces of ſtrong ſpirit of ſalt. Leaf ſilver is alſo ſaid to be corroded by ſtrong ſpirit of ſalt, I NEWM. 70. The dephlogiſticated marine acid alſo diſſolves it, according to the obſervations of Meſſ. SCHEELE and BERGMAN: and ſo does the phlogiſticated in a vaporous ſtate. 100 grs. of horn ſilver contain 75 of ſilver, nearly 18 of acid, and 7 of water.

Gold in aqua regia.

I made ſeveral experiments with aqua regia, in which the nitrous and marine acids were mixed in different proportions, and found *that* to ſucceed beſt, in which the quantity of real marine acid was to that of the nitrous as 3 to 1, and both as concentrated as poſſible; though if both be very concentrated, it is hard to mix them ſo as to prevent a great quantity from eſcaping, as they efferveſce very violently ſome time after mixture. 100 grs. of gold require 246 grs. real acid for their ſolution, the two acids being in the above mentioned proportion.

The ſpecific gravity of the nitrous acid I uſed was 1,465, and that of the marine 1,178. The ſolution is better promoted by allowing it ſufficient time than by applying heat. The heat I uſed did not exceed 90 or 100°. Very little air is produced, and the ſolution is very ſlow. Aqua regia made with common ſalt or ſal ammoniac and ſpirit of nitre is much leſs aqueous, than that reſulting from an immediate combination of both acids; and hence is the fitteſt for the production of cryſtals of gold.

Gold is alſo ſoluble in the dephlogiſticated marine acid, but in very ſmall quantity, unleſs this acid be in a vaporous ſtate, for in a liquid ſtate it is too aqueous. In vitriolic and nitrous acids it is alſo inſoluble; but the calces of gold are eaſily ſoluble in the marine acid, very ſlightly in the nitrous, and ſcarce at all in the vitriolic. Gold in its metallic ſtate may be diffuſed through, but not diſſolved, by the concentrated nitrous acid.

Mercury in vitriolic acid.

100 grs. of quickſilver require for their ſolution 230 grs. of real vitriolic acid, whoſe proportion to that of water is at leaſt as 1 to $\frac{8}{10}$, and alſo a ſtrong heat. The air produced is vitriolic. Precipitate, *per ſe*, is ſtill leſs ſoluble.

100 grs. of vitriol of mercury, produced by precipitation, contain 77 of mercury, 19 of acid, and 4 of water.

Mercury in nitrous acid.

100 grs. of mercury are diſſolved by 28 grs. of real nitrous acid, whoſe proportion to that of water is as 1 to 1 and $\frac{52}{100}$, and without the aſſiſtance of heat. Mercury is alſo ſoluble, but in ſmaller quantity, in a much more dilute acid, with the aſſiſtance of heat. The product of air is about 12 cubic inches or leſs, if heat be not applied. Mr. LAVOISIER found the product of air much greater, which evidently was cauſed by his uſing red or yellow ſpirit of nitre, which already contains much phlogiſton. When I diſſolved a hundred grs. of mercury in three times more acid than was neceſſary for its ſolution, and without heat, I obtained but 7 cubic inches of nitrous air, and the ſolution was green; but, on applying heat when the ſolution was over, I obtained 2 more cubic inches, and then the ſolution was of the colour of oil of olives.

Precipitate, *per ſe*, is much more difficultly diſſolved by nitrous acid than genuine mercury, which I attribute to the attraction of the aërial acid contained in the precipitate.

Mercury in marine acid.

The marine acid, in its common phlogiſticated ſtate, does not act on mercury, at leaſt in its uſual ſtate of concentration;

but Mr. HOMBERG, in the Paris Memoirs for the year 1700, aſſures us, he diſſolved mercury in marine acid, whoſe ſpecific gravity was 1,300, by keeping it ſome months in digeſtion. The authors of the *Cours de Chymie de Dijon* affirm alſo its ſolubility in this acid, though in very ſmall quantity. The dephlogiſticated marine acid, in a vapourous ſtate, certainly acts upon it, though while in a liquid ſtate it is too weak, by reaſon of its dilution.

Precipitate, *per ſe*, is alſo ſoluble in marine acid, with the aſſiſtance of heat. 100 grs. of ſublimate corroſive contain 77 of mercury, 16 of real acid, and 6 of water. 100 grs. of mercurius dulcis contain 86 of mercury, and 14 of acid and water.

Zinc in vitriolic acid.

100 grs. of zinc require for their ſolution 100 grs. of real acid, whoſe proportion to that of water may be as 1 to 8, 10, or 12, applying heat towards the end, when the acid is almoſt ſaturated. A ſmall quantity of black powder always remains undiſſolved. The product of inflammable air is 100 cubic inches. It is ſoluble in the concentrated vitriolic acid, with the aid of heat.

100 grs. of vitriol of zinc contain 20 of zinc, 22 of acid, and 58 of water.

The calces of zinc, if not exceedingly dephlogiſticated, are alſo ſoluble in this acid.

Zinc in nitrous acid.

100 grs. of zinc require for their ſolution 125 grs. of real nitrous acid, whoſe proportion to that of water is as 1 to 12, applying from time to time a ſlight heat. If a concentrated acid

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be uſed, leſs will be diſſolved, as much of the acid will eſcape during the efferveſcence. I could procure no nitrous air from the ſolution by any management, as the nitrous acid is in part decompoſed during the operation.

The calces of zinc, if not too much dephlogiſticated, are alſo ſoluble in this acid.

Zinc in Marine Acid.

The ſame quantity of zinc requires of this acid 210 grs. the proportion of real acid in the menſtruum being as 1 to 9, and uſing from time to time a ſlight heat. If a leſs dilute acid be uſed, more real acid will be requiſite, as much of it will eſcape during the efferveſcence.

The calces of zinc are alſo ſoluble in this acid.

Biſmuth in vitriolic acid.

200 grs. of oil of vitriol, whoſe ſpecific gravity was 1,863, diſſolved but three grs. of wiſmuth in a ſtrong heat; but ſlightly dephlogiſticated a greater quantity. 400 grs. of ſpirit of vitriol, whoſe ſpecific gravity was 1,200, diſſolved but one grain. The calces of wiſmuth are much more ſoluble. The ſolution of the 3 grs. afforded 4 cubic inches of vitriolic air.

Biſmuth in nitrous acid.

The ſolution of 100 grs. of biſmuth require but 100 grs. of real nitrous acid, whoſe proportion to water ſhould be as 1 to 8 or 9. In this laſt caſe, a gentle heat may be applied. This ſolution affords 44 cubic inches of nitrous air. The calces of biſmuth are alſo ſoluble in this acid.

Biſmuth in marine acid.

400 grs. of ſpirit of ſalt, whoſe ſpecific gravity is 1,220, diſſolved only 3 or 4 grs. of biſmuth.

Nickel in vitriolic acid.

100 grs. of concentrated vitriolic acid diſſolve about 4 of nickel, with the aſſiſtance of a ſtrong heat. The calces of nickel are much more ſoluble.

Nickel in nitrous acid.

100 grs. of nickel require for their ſolution 112 grs. of nitrous acid, whoſe proportion to water is as 1 to 11 or 12, aſſiſted with a moderate heat. A concentrated acid acts ſo rapidly that much is diſſipated. The product of nitrous air is 79 cubic inches. The calces of nickel are alſo ſoluble in this acid.

Nickel in marine acid.

200 grs. of ſpirit of ſalt, whoſe ſpecific gravity is 1,220, diſſolved 4 or 5 grs. of nickel, without the aſſiſtance of heat. A weaker acid diſſolves leſs, and requires the aſſiſtance of heat. In all theſe caſes of difficult ſolution more of the metal will be taken up by diſtillation and cohobation ; but the proportion will be difficult to aſſign.

The calces of nickel are alſo difficultly ſoluble in this acid.

Cobalt in vitriolic acid.

100 grs. of cobalt require 450 grs. of real acid, whoſe proportion to its water is not leſs than 1 to $\frac{7}{10}$, and a heat of

270° at leaſt. By pouring warm water on the dephlogiſticated maſs a ſolution is obtained.

The calces of cobalt are ſtill more ſoluble; even a dilute acid will ſerve.

Cobalt in nitrous acid.

100 grs. of cobalt requires 220 grs. of real nitrous acid, whoſe proportion to water is as 1 to 4, giving towards the end a heat of 180°.

The calces of cobalt are ſoluble in this acid.

Cobalt in marine acid.

100 grs. of ſpirit of ſalt, whoſe ſpecific gravity is 1,178, diſſolves, with the aſſiſtance of heat, 2½ grs. of cobalt. A more concentrated acid will diſſolve more.

The calces of cobalt are more ſoluble in this acid.

Regulus of antimony in vitriolic acid.

100 grs. of regulus of antimony require for their ſolution 725 grs. of real acid, whoſe proportion to water is as 1 to $\frac{7}{10}$, and a heat of 400°. More regulus ſhould be employed than is expected to be diſſolved, and the reſulting ſalt requires a large quantity of water to diſſolve it; for the concentrated acid lets fall much when water is added to it. A leſs concentrated acid will alſo diſſolve this ſemi-metal, but in ſmaller quantity.

The calces of antimony, even diaphoretic antimony, are ſomething more ſoluble.

Regulus of antimony in nitrous acid.

100 grs. of this ſemi-metal require 900 grs. of real nitrous acid, whoſe proportion to water is as 1 to 12, aided with a

heat of 110°. The ſolution, however, becomes turbid in a few days.

The calces of antimony are ſoluble in a much leſs degree.

Regulus of antimony in marine acid.

100 grs. of ſpirit of ſalt, whoſe ſpecific gravity is 1,220, diſſolve about 1 gr. of regulus, with the aſſiſtance of a ſlight heat. Spirit of ſalt, whoſe ſpecific gravity is 1,178, alſo acts upon it, but diſſolves ſtill leſs. I believe the concentrated acid would, in a long time, and with the help of a gentle heat, diſſolve much more of it.

The calces of antimony are much more ſoluble in this acid.

Regulus of arſenic in vitriolic acid.

200 grs. of oil of vitriol, whoſe ſpecific gravity is 1,871, diſſolve 18 of regulus of arſenic in a heat of 250°. Of theſe about 7 cryſtalize on cooling, and are ſoluble in a large quantity of water.

The calces of arſenic are more ſoluble in this acid.

Regulus of arſenic in nitrous acid.

100 grs. of this ſemi-metal require 140 grs. of real nitrous acid, whoſe proportion to water is as 1 to 11, and the aſſiſtance of heat. It is ſoluble in a leſs or more concentrated acid, but in a leſſer degree. This ſolution affords 102 cubic inches of nitrous air. The barometer at 30, and the thermometer at 60.

The calces of arſenic are alſo ſoluble in this acid.

Regulus of arſenic in marine acid.

100 grs. of ſpirit of ſalt, whoſe ſpecific gravity is 1,220, diſſolve 1½ grs. of regulus of arſenic; the marine acid, in its

common dilute ſtate, that is, whoſe ſpecific gravity is under 1,17, does not at all affect it.

The calces of arſenic are leſs ſoluble in this acid than in the vitriolic or nitrous.

We have now gone through moſt of the baſes to which acids are capable of uniting (manganeſe and platina I have purpoſely omitted, as I was not poſſeſſed of a ſufficient quantity of either in that degree of purity requiſite for exact experiments). We have alſo ſeen the quantity of the mineral acids requiſite to ſaturate each baſis, except the metallic baſes, all of which require an exceſs of acid, not only to diſſolve them, as in moſt caſes much of it flies off with the phlogiſton in an aërial form, but alſo to keep them in ſolution. The quantity of any baſis, taken up by a given quantity of any of theſe acids, is eaſily found; for if 100 grs. of any baſis take up, at the point of ſaturation, or require for their ſolution, the quantity a of any acid, the quantity taken up or diſſolved by 100 grs. of that acid will be $\frac{10000}{a}$.

The proportion of ingredients which I have aſſigned to different neutral ſalts appears, at firſt ſight, very different from that which Mr. BERGMAN has aſcribed to them. This for ſome time made me very uneaſy, as I have the higheſt confidence in the ſkill and judgement of that excellent chymiſt; but on a ſtrict examination I have found, that the difference is more apparent than real. Mr. BERGMAN has never attempted to aſcertain the quantity of *real* acid in any ſubſtance; but has, according to the cuſtom of all preceding writers, beſtowed the title of *acid* on thoſe liquids which contain it in the moſt concentrated, or at leaſt in a very concentrated ſtate, but which ſtill confeſſedly contain ſome undetermined proportion of water, and by the quantity of water he commonly underſtands that which is retained by cryſtallization: thus, in his firſt vol. p. 137. he ſays, that 100 grs. of vitriol of iron contain 23 of iron, 39 of vitriolic acid, and 38 of water. But in his treatiſe *De Productis Vulcanicis*, § 12. he ſays, that 100 grs. of vitriol of iron contain 24 of iron, 24 of *dephlegmated* vitriolic acid, and 52 of water; and this laſt calculation ſcarcely differs from mine, as I aſſign to 100 grs. of vitriol 25 of iron, 20 of real vitriolic acid, and 55 of water. The difference manifeſtly ariſes from the quantity of water ſtill contained in his dephlegmated acid. The moſt material difference between us regards the quantity of the mineral acids taken up by alkalies; for, according to his and Mr. SCHEFFER's experiments, they take up more of the vitriolic than of the nitrous, and more of the nitrous than of the marine; whereas, according to Mr. HOMBERG's, Dr. PLUMMER's, Mr. WENZEL's, and my experiments, this does not happen. This difference ariſes in all probability from the different degrees of evaporation by which the cryſtals of theſe ſalts are obtained; for which reaſon I did not examine the quantity of the cryſtals, which muſt be variable, but that of dry ſalt, left after thorough evaporation. With regard to the quantity of earth and metallic baſis in different ſalts, Mr. BERGMAN's experiments and mine agree almoſt intirely.

The advantages reſulting from theſe inquiries are very conſiderable, not only in promoting chymical ſcience, which, being a phyſical analyſis of bodies, eſſentially requires an exact determination, as well of the quantity and proportion, as of the quality of the conſtituent parts of bodies, but alſo in the practical way. Thus, in the firſt place, it is well known, that ſeveral important proceſſes are very inaccurately deſcribed by antient chymical writers, and even by ſome of a modern date, they frequently, for inſtance, deſcribe the acid they employed by reference to the quantity of fixed alkali, earth, or metal, a given quantity of ſuch acid was capable of neutralizing or diſſolving. Now the foregoing obſervations immediately inform us of the quantity of real acid capable of performing that effect; the remainder, therefore, muſt have been water; and the quantity of real acid and water being known, the ſpecific gravity is eaſily found by the help of the foregoing tables, and thus an acid of the ſame ſtrength may be formed. Thus SCHLUTTER, in the beſt treatiſe on Eſſaying yet extant*, informs us, that the beſt aqua fortis for parting ſilver from gold is that of which a pound diſſolves one mark, that is, half a pound of ſilver: then 1000 grs. of it ſhould diſſolve 500 of ſilver. Now, by the foregoing experiments, we find, that 100 grs. of alloyed ſilver require 38 of real acid for their ſolution; conſequently 500 grs. of ſilver will require 190 grs.; conſequently 1000 grs. of ſuch ſpirit of nitre ſhould contain 190 grs. of real acid and 810 of water. Then recurring to the table of the nitrous acid, I find, by the rule of proportion, that the ſpecific gravity of this acid muſt be about 1,261; for as 190 is to 810, ſo is 393 acid to 1675 of water. This proportion of water is ſomewhat greater than that I uſed, but SCHLUTTER uſes a ſand heat.

2dly, The importance of this knowledge in the art of pharmacy is very obvious, eſpecially with regard to medicines formed of metallic ſubſtances, whoſe powers depend on the proportion of their ingredients, and their action on each other.

3dly, This degree of preciſion muſt tend conſiderably to the improvement of the arts of dying and enamelling, the proceſſes by which many of their ingredients are procured being at preſent much too vague. Thus the proceſs at preſent uſed for preparing the precipitate of CASSIUS frequently fails, the ſtrength of the acids not being ſufficiently aſcertained.

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* Vol. I. p. 332. French edition.

4thly, The uſes of this knowledge in the examination of mineral waters, and in eſſaying of ores, have been amply proved in the elaborate treatiſes which the celebrated BERGMAN has lately given us on theſe ſubjects. And I may further add, that the knowledge of the quantity of acid requiſite for the ſolution of different metallic ſubſtances may alſo furniſh us with a new criterion for diſtinguiſhing them from each other, and the purer from their alloys, and in ſome caſes inform us of the quantity and quality of the alloy: thus, 100 parts pure ſilver require leſs of the nitrous acid to diſſolve them than 100 grs. of ſtandard ſilver; thus alſo, by diſſolving in ſpirit of ſalt any metallic ſubſtance ſufficiently ſoluble therein, we may know whether it contains the ſmalleſt particle of ſilver, quickſilver, or arſenic, as theſe are almoſt inſoluble therein, or of regulus of antimony, cobalt, nickel, or wiſmuth, of which it alſo takes but a ſmall proportion.

But the end which of late I had principally in view, was to aſcertain and meaſure the degrees of affinity or attraction that ſubſiſt betwixt the mineral acids, and the various baſes with which they may be combined, a ſubject of the greateſt importance, as it is upon this foundation that chymiſtry, conſidered as a ſcience, muſt finally reſt; and though much has been already done, and many general obſervations laid down on this head, yet ſo many exceptions have occurred even to ſuch of theſe obſervations as ſeemed to have been moſt firmly eſtabliſhed, that not only a variety of tables of affinity have been formed, but many very eminent chymiſts have been induced to doubt, whether any general law whatſoever could be traced. But, as the judicious BERGMAN well obſerves, it were much more reaſonable to examine the circumſtances of theſe exceptions, which undoubtedly ariſe from the introduction of new powers, and lay down rules qualified with ſuch reſtrictions as are obſerved in the action of theſe antagoniſt powers. This is the plan I have followed; but before I proceed to explain myſelf, I muſt open the ſubject in a more general way.

Chymical affinity or attraction is that power by which the inviſible particles of different bodies intermix and unite with each other ſo intimately as to be inſeparable by mere mechanical means. In this reſpect it differs from magnetic and electrical attraction. It alſo differs from attraction of coheſion in this, that the latter takes place betwixt particles of almoſt all ſorts of bodies whoſe ſurfaces are brought into immediate contact with each other; for chymical attraction does not act with that degree of indifference, but cauſes a body already united to another to quit that other and unite with a third, and hence it is called *elective* attraction. Hence attraction of coheſion often takes place betwixt bodies that have no chymical attraction to each other; thus regulus of cobalt and wiſmuth have no chymical attraction to each other, for they will not unite in fuſion, yet they cohere with each other ſo ſtrongly, that they can be ſeparated only by a ſtroke of a hammer.

Hence bodies, which refuſe to unite to each other chymically when they are moſt minutely divided, as when both are in a vaporous or aërial ſtate, or when both are in a liquid ſtate, may be judged, in the firſt caſe, to have none; or in the ſecond caſe, to have at beſt but a very ſmall affinity to each other. But thoſe that unite, when one of them only is in a liquid ſtate, may be ſaid to have a ſtrong affinity to each other, and it is thus that acids unite to alkalies, earths, and metals, for the moſt part.

In order to determine the degrees of affinity, Mr. GEOFFROY has laid it down as a general rule, that when two ſubſtances are united, and either quits the other to unite to a third, that which thus unites to this third ſubſtance muſt be ſaid to have a greater affinity to it than to the ſubſtance it has quitted. This undoubtedly is the caſe when only two attractive powers are concerned; thus, when ſelenite is decompoſed by a cauſtic fixed alkali, it is evident, that the vitriolic acid has a ſtronger affinity to the alkali than to the earth; but in many caſes a decompoſition, ſeemingly ſingle, is in fact double, and the reſult of the action of more than two powers, and then it is not eaſy to know which is the greateſt, nor conſequently to determine the degree of attraction; for inſtance, the vitriolic acid unites to a mild fixed alkali, and expels the fixed air from it, yet it does not neceſſarily follow, that the vitriolic acid attracts, or is attracted, by the alkali more ſtrongly than the aërial acid; for though there appears here only a ſingle decompoſition, yet in reality a ſort of double decompoſition takes place, the vitriolic acid giving out its fire to the aërial, while the aërial reſigns the alkali to the vitriolic; and hence a decompoſition might well take place, even on the ſuppoſition that the affinity of both acids to the alkali was equal: therefore, to attain any certainty in this matter, it is neceſſary to aſcertain the quantity and force of each of the attractive powers, and denote it by numbers.

Mr. MORVEAU was the firſt who perceived the neceſſity of this calculation, and he has accordingly communicated to us, in numbers, a table of the attractive power of mercury with reſpect to metals; but his method is incapable of being generalized.

fized. Mr. WENZEL had alſo an eye to ſuch calculation; but his method is much more defective. It is only this, "To "diſcover (ſays he) the quantity of affinity which the nitrous "acid bears to the different ſubſtances with which it is capable "of uniting, let ſmall equal cylinders of each of the metals "be covered over, except at one end, with melted amber, and "then expoſed to equal quantities of the ſame ſpirit of nitre, "and in the ſame temperature; then let the times of the ſolution of each be noted. *The affinity of the acid to each of theſe "metals will be inverſely as the times neceſſary for the ſolution of "equal quantities of them.*" And as he well knew that ſpirit of nitre, of the ſame degree of concentration, would not act equally on each of them, he required that it ſhould be diluted in ſome caſes, and undiluted in others, and allowance to be made for this in the ſubſequent calculation. But alkalies and earths are here intirely omitted; and even as to metals no concluſion can be drawn by this method. Tin and regulus of antimony are moſt rapidly attacked by this acid, lead and copper much more ſlowly; yet it is well known, that its affinity to lead is much ſtronger than its affinity to tin, and its affinity to copper greater than to regulus of antimony. Silver and quickſilver are more ſlowly diſſolved, and yet the affinity of the nitrous acid to theſe metals, as will be ſeen in the ſequel, is by far the greateſt.

Neither can this method be in any wiſe applied to the eſtimation of the affinities of the other mineral acids; for though the vitriolic and marine acids diſſolve very ſlowly, difficultly, and ſparingly, ſeveral metals that are copiouſly and readily diſſolved by the nitrous, yet they both have a ſtronger affinity to thoſe very metals than the nitrous has to them, as is evident with regard to ſilver, mercury, and lead, which are precipitated from the nitrous by the vitriolic and marine, though the two firſt are inſoluble in the marine, and all three difficultly ſoluble in the vitriolic. Accordingly, we do not find that Mr. WENZEL has ever made the propoſed experiments, at leaſt he makes no mention of their reſult.

The diſcovery of the quantity of real acid in each of the mineral acid liquors, and the proportion of real acid, taken up by a given quantity of each baſis at the point of ſaturation, led me unexpectedly to what ſeems to me the true method of inveſtigating the quantity of attraction which each acid bears to the ſeveral baſes to which it is capable of uniting; for it was impoſſible not to perceive,

Firſt, That *the quantity of real acid, neceſſary to ſaturate a given weight of each baſis, is inverſely as the affinity of each baſis to ſuch acid.*

Secondly, That *the quantity of each baſis, requiſite to ſaturate a given quantity of each acid, is directly as the affinity of ſuch acid to each baſis.*

Thus 100 grs. of each of the acids require for their ſaturation a greater quantity of fixed alkali than of calcareous earths, more of this earth than of volatile alkali, more of this alkali than of magneſia, and more of magneſia than of earth of allum, as may be ſeen in the following table.

Quantity of baſis taken up by 100 grs. of each of the mineral acids.

	Veg fixed alkali. Grs.	Min. alkali. Grs.	Calcar. earth. Grs.	Vol. alkali. Grs.	Magneſia. Grs.	Earth of allum. Grs.
Vitriolic acid	215	165	110	90	80	75
Nitrous acid	215	165	96	87	75	65
Marine acid	215	158	89	79	71	55

As theſe numbers agree with what common experience teaches us concerning the affinity of theſe acids with their reſpective baſes, they may be conſidered as adequate expreſſions of the quantity of that affinity, and I ſhall in future uſe them as ſuch. Thus the affinity of the vitriolic acid to fixed vegetable alkali, that is, the force with which they unite, or tend to unite, to each other, is to the affinity with which that ſame acid unites to calcareous earth as 215 grs. to 110; and to that which the nitrous acid bears to calcareous earth as 215 grs. to 96, &c. But before I proceed further in the compariſon of theſe forces, it is neceſſary to ſay ſomething of the nature of *ſaturation*.

A body is ſaid to be *ſaturated* with another, when it is ſo intimately combined with that other as to loſe ſome peculiar characteriſtic property, which it poſſeſſes when free from that other. Thus acids poſſeſs the property of changing the juice of turnſol, or infuſion of litmus, *red*. According to Mr. BERGMAN one grain of the moſt concentrated oil of vitriol will give a viſible redneſs to 172,300 grs. of this infuſion, and one cubic inch of water, ſaturated with fixed air (the weakeſt of all acids, as is generally thought) of which water takes up only about its own bulk, and conſequently 253 grs. take up only about half a grain, reddens 50 cubic inches, that is, about 12,650 grs. of the infuſion. When acids loſe this property they are ſaid to be ſaturated: and if both bodies are ſaturated, the compound is ſaid to be *neutralized*.

If an acid be united to leſs of any baſis than is requiſite for its ſaturation, its affinity to the deficient part of its baſis is as the ratio which that deficient part bears to the whole of what the acid can ſaturate. Thus if 100 grs. of vitriolic acid be united to 55 parts only of calcareous earth, its affinity to the deficient

55 parts ſhould be eſtimated half of its whole affinity, as 55 is the half of 110; but its affinity to the retained part is as its whole affinity.

I ſhall now ſhew how all decompoſitions, in which theſe three acids and the above mentioned baſes are alone concerned, may eaſily be explained.

In all decompoſitions we muſt conſider, firſt, the powers which reſiſt any decompoſition, and tend to keep the bodies in their preſent ſtate; and, ſecondly, the powers which tend to effect a decompoſition and a new union. The firſt I ſhall call *quieſcent* affinities, and the ſecond ſort *divellent.*

A decompoſition will always take place when the ſum of the divellent affinities is greater than that of the *quieſcent*; and, on the contrary, no decompoſition will happen when the ſum of the *quieſcent* affinities is ſuperior to, or equal to, that of the *divellent*: all we have to do, therefore, is to compare the ſums of each of theſe powers. Thus, if the ſolutions of tartar vitriolate and nitrous ſelenite be mixed, a double decompoſition will take place, a true ſelenite and nitre being the reſult of ſuch mixture.

Quieſcent affinities.		Divellent affinities.	
Vitriolic acid to fixed veget. alkali	215	Vitriolic acid to calcareous earth	110
Nitrous acid to calcareous earth	96	Nitrous Acid to vegetable alkali	215
Sum of the quieſcent affinities	311	Sum of the divellent —	325

Hence a double decompoſition muſt neceſſarily happen.

The ſame double decompoſition will be produced if, inſtead of tartar vitriolate, GLAUBER's ſalt be uſed, 1 MARGR. 392.; for the ſum of the quieſcent affinities is 261, and that of the divellent 275. So alſo, if *vitriolic ammon.* be uſed for the ſum of the quieſcent is 186, and that of the divellent 195, or Epſom ſalt, 1 MARGR. 390. Mem. Par. 1778, p. 339. or *allum*, 1 MARGR. 387. The determinations, however, with regard to allum are not quite ſo exact as the foregoing; becauſe allum, whether vitriolic, nitrous, or marine, conſtantly retains an exceſs of acid, the exact point of ſaturation cannot be found as I have already remarked, and is well known: however, the ſuperiority is on the ſide of the divellent affinities, as it ſhould be. If, inſtead of a ſolution of nitrous ſelenite, that of marine ſelenite be mixed with the ſolutions of the above mentioned vitriolico-neutral ſalts, the ſame ſort of double decompoſition will happen, and a true ſelenite will be formed, 1 MARGR. 382; and on calculation it will be conſtantly found, that the ſum of the divellent conſtantly exceeds that of the quieſcent affinities.

So alſo, if a ſolution of tartar vitriolate be mixed with a ſolution of nitrous or marine Epſom, a double decompoſition will take place, though no viſible change will appear in the mixed liquor, as vitriolic Epſom is exceeding ſoluble in water, and therefore is not precipitated as ſelenite is, on account of its inſolubility, Mem. Par. 1778, p. 338. In the firſt caſe, the ſum of the quieſcent powers is 290, and of the divellent 295; in the ſecond caſe, that of the quieſcent is 286, and of the divellent 295.

If a ſolution of GLAUBER's ſalt be mixed with that of nitrous or marine Epſom, an inviſible double decompoſition will alſo happen, Mem. Par. ibid. Hence Mr. QUATREMERE DIJON-VAL, who lately denied this double decompoſition (ROZ. Mai 1782, p. 392.) was certainly deceived. In the firſt caſe, the ſum of the quieſcent affinities is 240, and of the divellent 245; in the ſecond caſe, that of the quieſcent is 236, and of the divellent 238. Further, if a ſolution of nitre be mixed with a ſolution of marine ſelenite, an inviſible double decompoſition will enſue, Mem. Par. 1778, p. 341.; the ſum of the quieſcent powers being 304, and of the divellent 313.

If a ſolution of nitrous Epſom be mixed with that of marine ſelenite, a double decompoſition will be the conſequence, 17 ROZ. 393.: the ſum of the quieſcent affinities being 164, and that of the divellent 167.

From all which I collect, firſt, that the quantity of each affinity, as here determined, perfectly coinciding with all the facts hitherto known, which are pretty numerous, may be looked upon as exact or nearly ſo. 2dly, That theſe decompoſitions are perfectly conſiſtent with the ſuperior affinity which hitherto has been generally aſcribed to the vitriolic and nitrous acids with fixed alkalies over that which theſe acids bear to earths, and do not in the leaſt infringe the received laws of affinities, as Meſſ. MARHER, MONNET, and lately Mr. CORNETTE, in the Memoirs of Paris for 1778, p. 339. do inſinuate.

There is a fact, however, in that valuable repoſitory of chymical knowledge, Mr. CRELL's Chymical Journal *, which at firſt ſight ſeems contrary to one of the above determinations; it is there ſaid, that if ſolutions of one part allum and two parts common ſalt be mixed together, evaporated to a certain degree, and ſet to cryſtallize, a GLAUBER's ſalt will be found; yet in this caſe the ſum of the quieſcent affinities is 233, and that of the divellent but 223. I repeated this experiment without ſucceſs, and indeed the author owns it never ſucceeds but during the moſt intenſe cold.

If it does ſucceed at all, the decompoſition muſt ariſe from a large exceſs of acid in the allum, which acted upon and de-

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* 6 THEIL. p. 78.

compoſed the common ſalt; and this explanation is confirmed by the ſmall proportion of GLAUBER's ſalt, which is ſaid to be obtained by this proceſs; for from 30 lbs. of common ſalt and 16 lbs. of allum only, 15 lbs. of GLAUBER's ſalt were produced; whereas, if the whole of the allum were decompoſed, there ſhould be formed, according to my computation of the proportion of acid in different ſalts, 29½ lbs., and, according to Mr. BERGMAN's, 22 lbs. of GLAUBER's ſalt.

Beſides theſe powers there exiſts another which neutral ſalts poſſeſs, of uniting to certain ſubſtances, without ſuffering any, or but a very ſmall, decompoſition; and thus forming *triple* ſalts, and ſometimes quadruple. This often cauſes anomalies, and has not as yet been ſufficiently inveſtigated *. Volatile alkalies in particular poſſeſs this power; and hence, perhaps, ariſes the difference between Mr. BERGMAN's table and mine, with regard to them and magneſia; for though, when perfectly cauſtic, they do not perfectly precipitate magneſia from Epſom ſalt, it is becauſe they combine with this ſalt and form a triple ſalt.

According to my table, the three mineral acids have the ſame affinity to vegetable fixed alkalies, which will undoubtedly appear extraordinary to many, as it is well known, that the vitriolic acid decompoſes both nitre and ſalt of ſylvius; but it ſhould be remarked, that tartar vitriolate is alſo decompoſed by the nitrous and marine acids, as Mr. BAUMÉ, MARGRAAF, and BERGMAN, have found; and nitre is decompoſed by the marine acid, as Mr. CORNETTE has ſhewn at large in the Memoirs of Paris for 1778; and not only theſe ſalts, but alſo GLAUBER's ſalt and vitriolic ammoniac, are decompoſed by the nitrous acid; and alſo theſe ſalts, together with cubic nitre and nitrous ammoniac, are decompoſed by the marine acid, as Mr. BERGMAN and Mr. CORNETTE have remarked: all which ſhew, that theſe decompoſitions are the effect of a double affinity, or at leaſt of compound forces. I always ſuſpected they aroſe from the different capacities of theſe acids for elementary fire; but as the ſubject appeared to me of importance, for greater certainty I made a ſeries of experiments which differ from thoſe hitherto made in ſeveral reſpects, particularly in this, that no heat was applied, and the decompoſitions were diſcovered, not by cryſtallization, but by teſts.

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* In my next paper I ſhall examine ſome exceptions ariſing from this ſource.

Firſt, I procured equal weights of each of the mineral acids, containing each the ſame quantity of real acid; and throwing each ſuddenly on an ounce of the ſame oil of tartar, I had the following reſults, the temperature of all, before mixture, being 68° of FAHRENHEIT. 100 grs. of vitriolic acid, containing 26,6 grs. of real acid projected on 480 of oil of tartar, raiſed the thermometer to 138°.

100 grs. of ſpirit of nitre, which alſo contained 26,6 grs. real acid, projected in the ſame manner on 480 grs. of the ſame oil of tartar, produced a heat of 120°.

100 grs. of ſpirit of ſalt, whoſe ſpecific gravity was 1,220, and which contained 26,6 grs. of real acid, projected on the above quantity of the ſame oil of tartar, raiſed the thermometer from 69 to 129°.

Hence it follows, that the vitriolic acid contains more ſpecific fire, or at leaſt gives out more on uniting to fixed alkalies, than either the nitrous or marine; and, therefore, when the vitriolic acid comes in contact with either nitre or ſalt of ſylvius, its fire paſſes into theſe acids, which are thereby rarefied to a great degree, and are thus expelled from their alkaline baſis, which is then ſeized on by the vitriolic. This explanation is confirmed by the following experiments.

Into 400 grs. of ſpirit of vitriol, whoſe ſpecific gravity was 1,362, I put 60 grs. of nitre. The thermometer fell from 68 to 60, and during this time the nitrous acid was not expelled, for I put in ſome filings of copper, and they were not in the leaſt acted upon; but in five minutes after, they viſibly effervefced, which ſhews that the nitrous acid began to be expelled.

Again, to 400 grs of oil of vitriol, whoſe ſpecific gravity was 1,870, I put 60 grs. of nitre: the thermometer immediately roſe from 68 to 105°, and the nitrous acid was expelled in the form of a viſible fume. Theſe experiments prove, firſt, that neutral ſalts are not decompoſed, by mere ſolution, in an acid different from that which they poſſeſs. 2dly, That the nitrous acid, being converted into vapour, had imbibed a large quantity of fire. But as the vitriolic, in both theſe experiments, was in much larger quantity than was neceſſary to ſaturate the alkaline baſis of the nitre, I put 60 grs. of nitre into 64 of the above ſpirit of vitriol, which contained the ſame quantity of real vitriolic acid as the 60 grs. of nitre did of the nitrous, and added 40 grs. of water, and alſo a few grains of filings of copper. In leſs than two hours the copper was acted upon, and conſequently the nitrous acid was expelled.

Again to about 400 grs. of oil of vitriol, whoſe ſpecific gravity was 1,870, I put 100 grs. of common ſalt; it immediately efferveſced, and gave out the marine acid in the form of a white vapour. A thermometer held in the liquor roſe but 4°; but when placed in the froth it roſe to 10°, and fell again on being put into the liquor: whence it follows, that the vitriolic acid gave out its fire to the marine, and that this latter received more than it could abſorb even in the ſtate of vapour, and hence communicated heat to the contiguous liquor.

From theſe experiments it is evident, that the nitrous and marine acids receive fire from the vitriolic, and are thrown into a vapourous ſtate, or at leaſt ſo much rarefied as to be expelled from their alkaline baſis, notwithſtanding that their affinity to that baſis may be equally ſtrong with that of the vitriolic.

I next proceeded to examine how tartar vitriolate and GLAUBER's ſalt are decompoſed by the nitrous acid. Into 400 grs. of ſpirit of nitre, whoſe ſpecific gravity was 1,355, and which contained about 105 grs. of real acid, I put 60 of pulveriſed tartar vitriolate. The thermometer, which ſtood at 68°, was not in the leaſt affected by ſtanding in this mixture, and there was ſcarce any ſign of ſolution. To try whether the vitriolic acid was diſengaged, I threw into the liquor a few grains of powdered regulus of antimony: in 24 hours the vitriolic acid was in part diſengaged, for the regulus was acted upon, and the liquor became greeniſh. This ſemi-metal being ſoluble in a mixture of the vitriolic and nitrous acids, but in neither ſingly, however, a great part of the tartar vitriolate ſtill remained undiſſolved. Afterwards I put the ſame quantity of tartar vitriolate into 400 grs. of ſpirit of nitre, whoſe ſpecific gravity was 1,478; the thermometer roſe from 67 to 79°, the tartar vitriolate was quickly diſſolved, and the regulus of antimony ſhewed the vitriolic acid was diſengaged.

Hence it follows, that in the laſt experiment the nitrous acid having the ſame affinity to the alkaline baſis as the vitriolic, but giving out, during the ſolution, more fire than was neceſſary to perform the ſolution, the vitriolic receiving this fire was diſengaged; for as it cannot unite to alkalies without giving out fire, ſo when it receives back that fire it muſt quit them. The reaſon why the nitrous acid, which ſpecifically contains leſs fire than the vitriolic, gives out ſo much, is, that its quantity in both theſe experiments is far greater than that of the vitriolic, it being in the firſt as 105 to 17; and in the ſecond as 158 to 17.

For this reaſon, to 60 grs. of ſpirit of nitre, whoſe ſpecific gravity was 1,355, I added 1000 grs. of water, and into this dilute acid I put 60 grs. of tartar vitriolate, which contained exactly the ſame quantity of acid as the 60 grs. of ſpirit of nitre. After eight days the tartar vitriolate was almoſt intirely diſſolved, yet I could perceive no ſign of its decompoſition, and after evaporation no nitre was found. Hence I conclude, that the nitrous acid can never decompoſe tartar vitriolate without the aſſiſtance of heat, but when its quantity is ſo great that it contains conſiderably more fire, and by the act of ſolution is determined to give out this fire. The decompoſition of GLAUBER's ſalt and vitriolic ammon. (neither of which, as Mr. BERGMAN obſerved, is ever total) may be explained in the ſame manner; whereas the vitriolic, ever ſo dilute, decompoſes both nitre and nitrous ammoniac totally. Tartar vitriolate is alſo decompoſed by the marine acid, though very ſlowly, for the ſame reaſon, and in the ſame circumſtances, as it is decompoſed by the nitrous acid, as appears by the following experiments. Into 400 grs. of ſpirit of ſalt, whoſe ſpecific gravity was 1,200, I put 60 grs. of tartar vitriolate. The thermometer was not in the leaſt affected, and the ſalt diſſolved very ſlowly. To try whether the vitriolic acid was diſengaged, I added ſome pulveriſed biſmuth; in twelve hours part of the biſmuth was diſſolved, and could not be precipitated by the affuſion of water, a ſign that it was held in ſolution by the compound acid, which alone hath the property of preventing its precipitation by the affuſion of water, as Mr. WENZEL has diſcovered. Here the quantity of marine acid was much greater than that of the vitriolic, and conſequently it contained more fire; but this circumſtance alone is not ſufficient, it muſt beſides be determined to give out that fire by the act of ſolution. This appears by the experiments of Mr. CORNETTE; for when he mixed half an ounce of tartar vitriolate, *previouſly diſſolved* in water with two ounces of ſpirit of ſalt, the tartar vitriolate was not decompoſed, Memoirs, Paris, 1778, p. 49.; for it being already diſſolved, no cold or heat was generated by mixing it with the ſpirit of ſalt, and conſequently the latter did not give out any fire. Mr. CORNETTE alſo obſerved, that GLAUBER's ſalt is eaſier decompoſed by the marine acid than tartar vitriolate; this I have alſo experienced, and the reaſon is, firſt, becauſe GLAUBER's ſalt is more eaſily ſoluble in ſpirit of ſalt than tartar vitriolate; and, ſecondly, becauſe its alkaline baſis takes up a greater quantity of the real marine acid than of the vitriolic, whereas the baſis of tartar vitriolate takes up an equal quantity of both acids; conſequently the marine gives out more fire in uniting to the baſis of GLAUBER's ſalt than on uniting to that of tartar vitriolate.

Vitriolic ammoniac is alſo decompoſed by the marine acid for the ſame reaſon; but in all theſe caſes the quantity of the marine acid muſt much exceed that of the vitriolic, or no decompoſition will take place. The decompoſition of nitro-neutral ſalts by the marine acid depends on the ſame principles. Mr. CORNETTE found, that cubic nitre was more eaſily decompoſed than priſmatic nitre, and accordingly, during the ſolution of priſmatic nitre, only 3° of cold were produced; but, during that of cubic nitre, the thermometer fell 6°, a ſign that the ſpirit of ſalt gave out more fire in the latter caſe than in the former, and its quantity muſt always be greater than that of the nitrous acid contained in the mineral alkaline baſis, becauſe this baſis requires for its ſaturation more of the marine than of the nitrous acid, as we have already ſeen.

Yet the nitrous acid, in its turn, decompoſes ſalt of ſylvius and common ſalt, as Mr. MARGRAF has ſhewn; but it muſt always be in greater quantity than the marine, in order to contain a ſufficient quantity of fire for that effect. To 400 grs. of colourleſs ſpirit of nitre, whoſe ſpecific gravity was 1,478, I put 60 grs. of common ſalt, it quickly effervefced and grew red; yet the thermometer roſe but 2°, a ſign that the marine acid had abſorbed the greater part of the fire which the nitrous had given out, and was thus expelled: beſides, in this caſe, the ſuperior affinity of the nitrous acid to the mineral baſis haſtened the decompoſition; and hence the decompoſition happens without ſolution, whereas the marine acid does not decompoſe cubic nitre until it has diſſolved it, which is worthy of notice. This mutual expulſion of the nitrous and marine acids by each other is the true reaſon why aqua regia may be made, as well by adding nitre or nitrous ammoniac to ſpirit of ſalt, as by adding common ſalt or ſal ammoniac to ſpirit of nitre, as Mr. CORNETTE has well remarked.

Selenite is decompoſed neither by the nitrous nor by the marine acids, as Meſſ. CHAPTAL and CORNETTE have obſerved. The reaſon is evident on the above principles; it is diſſolved by neither without the aſſiſtance of heat, and then the ſolution is performed by a *foreign* heat, and not by that which theſe acids give out when they act without the aſſiſtance of heat.

Laſtly, whenever a vitriolico-neutral ſalt, decompoſed by either the nitrous or marine acid, is evaporated to a certain degree, the vitriolic expels theſe acids in its turn; for the free part of the former acids being expelled by the heat of evaporation, the neutral ſalts begin to cryſtallize, and conſequently give out heat; but the vitriolic being then in greater proportion re-acts on theſe ſalts, reſtores their ſpecific fire to their acid principle, and recombines with their alkaline baſis, as already explained.

Hence, though allum is in reality decompoſed by the nitrous and marine acids, yet when the ſolution of it in either of theſe acids is evaporated to a certain degree, the vitriolic acid, of which it contains a larger proportion than any other terrene ſalt, re-acts on the nitrous and marine allums, and expels their acids, as Mr. CHAPTAL has ſhewn.

In explaining theſe phenomena I have all along ſuppoſed the doctrine of Dr. BLACK to be well known, *viz.* that ſolids abſorb heat during their ſolution. Both the heat and cold, produced in different ſolutions, ſeem to me to depend on the ſame principle. If the menſtruum gives out only *ſo much* of its fire as the ſolvend can abſorb, or *leſs*, then cold is produced; but if it gives out *more* of its ſpecific fire than the ſolvend can abſorb, this ſurplus becomes ſenſible, and affects the thermometer by producing heat in proportion to its quantity.

Of the affinity of the mineral acids to metallic ſubſtances.

Having thus, in every inſtance, eſtabliſhed the agreement betwixt the quantity of any alkaline or terrene baſis, taken up at the point of ſaturation by a given weight of any of the three mineral acids, and the quantity of affinity which each of theſe acids bears to ſuch baſis, I naturally extended my views to metallic ſubſtances, to try whether this coincidence could be traced with regard to them alſo; but the difficulties that occurred in this inquiry were ſo great, that the ſame degree of certainty muſt not be expected as in the foregoing part.

Metallic ſubſtances, when freeſt from all foreign mixture, are obtained either in a reguline ſtate, or in that of a calx. Theſe calces, if formed by fire, are conſtantly combined with more or leſs of the aërial acid, which is very difficultly extracted from them, and very ſoon re-abſorbed; and if formed by ſolution, they as conſtantly retain a portion of their ſolvent or precipitant, ſo that the preciſe weight of the really metallic part is difficultly aſcertained. But though this ſhould eaſily be effected, ſtill they would for the moſt part be unfit for my purpoſe; becauſe moſt of them, when much dephlogiſticated, are inſoluble in ſome or all the acids: hence I choſe metals in their metallic ſtate for the ſubject of my experiments. Theſe conſiſt of ſpecifically different earths and phlogiſton, and of this they muſt loſe a part before they can be diſſolved in acids; but, beſides that which eſcapes in an aërial form, much more of it, though ſeparated from the metallic earth, is yet retained in the ſolution by the compound of acid and calx. It is this calx, thus differently dephlogiſticated by the different acids, whoſe proportion I endeavoured to aſcertain.

The great difficulty that occurred in this inquiry was, that of finding the exact quantity of acid neceſſary to ſaturate the metallic ſubſtances; for all metallic ſolutions turn ſolution of litmus red, and conſequently contain an exceſs of acid. And the reaſon is, becauſe the ſalts, formed by a due proportion of metallic calx and acid, are nearly inſoluble in liquids that do not contain a further quantity of acid; and in ſome caſes this quantity, and even its *proportion to the aqueous part of the liquor*, muſt be very conſiderable, as in ſolutions of biſmuth. Hence I in vain endeavoured, by cauſtic alkalies and lime-water, to deprive theſe ſolutions of this exceſs; for when deprived even of only part of it, many of the metals precipitated, and all would, if deprived of the whole of it. On this account I was obliged to uſe different methods, of which I ſhall here give an inſtance. With regard to the ſolution of ſilver in the nitrous acid, as it could be had extremely ſaturate I began with it. 657 grs. of this ſolution contained, according to my calculation, and allowing for the quantity of acid carried off in the nitrous air, 31,38 grs. of real acid, and 100 grs. of ſilver. Of this ſolution I found that 9 grs. gave a viſible *red tint* to as much of a dilute ſolution of litmus, as a quantity of ſpirit of nitre, which contained $\frac{8}{10}$ths of a grain of real acid, and therefore I judged theſe 9 grs. to contain an exceſs of acid, amounting to $\frac{8}{10}$ths of a grain; and if 9 grs. contain ſuch an exceſs, then the whole ſolution muſt have contained an exceſs amounting to $5\frac{6}{10}$ths of a grain, deducting which from 31,38, we find the quantity of acid ſaturated by 100 grs. of ſilver to be 25,78 grs. In this manner I proceeded with moſt other metallic ſolutions. The vitriolic ſolutions of tin, wiſmuth, regulus of antimony, nickel, and regulus of arſenic, containing a large exceſs of acid, I ſaturated part of it with cauſtic volatile alkali before I tried them with the infuſion of litmus, and I uſed the ſame expedient with the nitrous ſolution of iron, lead, tin, and regulus of antimony, and all the marine ſolutions. The proportion of vitriolic and marine acid taken up by lead, ſilver, and mercury, I determined by computing the quantity of real acid neceſſary to precipitate theſe metals from their ſolutions in the nitrous acid; and of all the determinations theſe appeared to me to be the moſt exact. However, as all the vitriols of theſe metals are, though in a ſlight degree, ſoluble in the nitrous acid, I was obliged to rectify the reſult from other conſiderations, and the ſame neceſſity occurred with regard to the marine ſalts of lead and mercury.

The reſult of theſe experiments was, that 100 grs. of each of theſe acids take up, at the point of ſaturation of each metallic ſubſtance, dephlogiſticated to ſuch a degree as is neceſſary for its ſolution in each acid, the quantities expreſſed in the following table, which denote their degree of affinity to each metal.

Table of the affinity of the three mineral acids to metallic ſubſtances.

100 grs.	Iron.	Copper.	Tin.	Lead.	Silver	Mercury.	Zinc.	Wiſmuth.	Nickel	Cobalt.	Reg. of antimo.	Reg. of arſenic.
Vitriolic acid	270	260	138	412	390	432	318	250 310	320	360	200	260
Nitrous acid	255	255	120	365	375	416	304	290	300	350	194	220
Marine acid	265	265	130	400	420	438	312	250 320	275 310	370	198	290

Yet I cannot ſay that theſe numbers are *preciſely* ſuch as I could extract from my obſervations on the colour of the ſolution of litmus; for theſe indications are ſo precarious that I did not abſolutely confide in them, but adjuſted the numbers, as I thought other phenomena required. However, the deviations were not ſo conſiderable as to induce a doubt that metallic earths had not almoſt all a ſtronger affinity to the three acids than even fixed alkalies. Nevertheleſs, the common tables, which poſtpone metallic ſubſtances to all others, are in reality juſt; they only require a different denomination, being in fact tables of *precipitation* rather than of *affinity*, as far as they relate to metallic ſubſtances, expreſſing by their *order*, what metallic ſubſtances precipitate others from the different acids. But theſe precipitations are conſtantly the reſult of a double affinity and decompoſition.

decompoſition, the *precipitating* metal yielding its phlogiſton to the *precipitated* metal, while the *precipitated* metal yields its acid to the *precipitant.* Nor has this eſcaped the ſagacity of Mr. BERGMAN, 2 N. Act. Upſ. 205. who has even confirmed it by experiments which I have repeated, and found exact. Thus, though copper, in its metallic form, precipitates ſilver and mercury from the nitrous acid with great eaſe, yet the calx of copper will precipitate neither. The ſuperior affinity of acids to metallic earths, in preference to alkalies and unmetallic earths, requiring further proof, I ſhall here demonſtrate it in a few inſtances, with regard even to thoſe metals which are commonly thought to have the leaſt affinity to acids. And, firſt, that the nitrous acid has a ſtronger affinity to ſilver than to fixed alkalies, appears by a curious experiment of Mr. MONNET's (Diſſolution des Metaux, p. 159.). If a ſolution of ſilver in nitrous acid be poured into a mixed ſolution of fixed alkali and common ſalt, the ſilver will be precipitated by the marine acid of the common ſalt, and not by the free alkali contained in the liquor, for a *luna cornua* is found. Now if the nitrous acid had a greater affinity to the free alkali than to the ſilver, it is evident, that the decompoſition would be wrought by the free alkali, and then the ſilver would be precipitated pure, and not in the ſtate of horn ſilver; but as it is precipitated in the ſtate of horn ſilver, it is plain, its precipitation was not effected by a ſingle but by a double affinity. From whence it alſo follows, that the marine acid has a greater affinity to ſilver than the nitrous has to fixed alkalies. I repeated this experiment with a ſolution of lead and alſo of mercury in the nitrous acid, and the reſult was ſimilar, horn lead and marine ſalt of mercury being formed.

With regard to mercury, the experiments of Mr. BAYEN are well known: he has ſhewn that vitriol of lead and ſub. corroſive can be deprived of no more than half of their acid even by cauſtic fixed alkalies, 3 ROZ. 293.

Again as to lead, if perfectly dry common ſalt be projected on lead heated to incandeſcence, the common ſalt will be decompoſed, and horn lead formed, 1 MARGRAF. 35 and 38. Nor can this be attributed to the volatilization of the acid by heat; for the alkali is as fixed as the lead, and muſt therefore be cauſed by the greater affinity of the calx of lead, to which, when dephlogiſticated, the acid can unite. Mr. SCHEELE informs us, that if a ſolution of common ſalt be digeſted with litharge, the common ſalt will be decompoſed, and a cauſtic alkali produced, SCHEELE on Fire, p. 175. He alſo decompoſes common ſalt by ſimply letting its ſolution ſlowly paſs through a funnel filled with powdered litharge. * Mr. TURNER daily decompoſes common ſalt by means of litharge. Mr. SCHEELE alſo decompoſes marine ſelenite, by means of litharge, through ſimple mixture, without the aſſiſtance of heat, and the calcareous earth is ſeparated in a cauſtic ſtate; which ſhews that this ſalt is decompoſed by the ſingle ſuperior affinity of the metallic calx to the marine acid, SCHEELE on Fire, p. 174.

That acids have leſs affinity to volatile alkalies than to ſeveral metallic ſubſtances appears in ſundry inſtances. Horn ſilver is ſoluble in volatile alkalies, as is well known. Now, if this ſolution be triturated with four times its weight of mercury, the marine acid will combine with the mercury, and not with the volatile alkali; for a *mercurius dulcis*, and not a ſal ammoniac, will be formed, as Mr. MARGRAF has ſhewn, 1 MARG. 286. If two parts ſal ammoniac and one of filings of iron be triturated together, the ſmell of the volatile alkali will immediately be perceived *; or if, inſtead of iron, minium, or diaphoretic antimony, or zinc, be uſed, that ſmell is perceived as ſoon as they are mixed, 9 Mem. Scav. Etrang. p. 575. MONNET, Diſſ. Met. 209. But it will naturally be aſked, how then it happens, that all metallic ſolutions are precipitated by alkalies and earths? The anſwer is eaſy; all metallic ſalts are held in ſolution by an exceſs of acid. If alkalies and earths did nothing more than abſorb this exceſs of acid, a precipitation ought to take place; but they do ſtill more, for they take up the greater part even of the proportion of acid neceſſary to ſaturate the metallic earth, and this they are enabled to do by means of a double affinity; for during the ſolution of metals, only a comparatively ſmall part of the phlogiſton eſcapes out of the ſolution, the remainder is retained by the compound of acid and calx: when, therefore, an alkali or earth is added to ſuch a ſolution, the phlogiſton quits the acid, and re-combines with the calx, while the greater part of the acid unites to the precipitant. Notwithſtanding this great affinity of metallic earths to acids, ſalts, whoſe baſis is a fixed alkali or earth, are in few inſtances decompoſed by metals or their calces, by reaſon of the inability of the acids while combined with theſe baſis, and thereby deprived of a great part of their ſpecific fire, to volatilize the phlogiſton combined with the metallic earths, which muſt neceſſarily be expelled before an acid can combine with them. And as to metallic calces, they are generally combined with fixed air, which alſo muſt be in part expelled.

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* SCHEFFER Chymiſche Foceles, § 59.

But ammoniacal ſalts, containing much more fire (for they abſorb fire during their formation) for that reaſon act much more powerfully on metals. Allowing then the affinity of the

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* MONNET, Diſſol. Met. 71.

mineral acids to metallic ſubſtances to be as above, all double decompoſition in which only ſalts, containing theſe acids united to alkaline terrene or metallic baſes, are concerned, admit of an eaſy explanation; nay, I am bold to ſay, they cannot otherwiſe be explained. Thus if a ſolution of tartar vitriolate, and of ſilver in the nitrous acid, be mixed in proper proportions (which is always to be underſtood), nitre and vitriol of ſilver will be formed, and this latter for the moſt part precipitated.

Quieſcent affinities.		Divellent affinities.	
Nitrous acid to ſilver -	375	Nitrous acid to vegetable alkali	215
Vitriolic acid to vegetable alkali	215	Vitriolic acid to ſilver	390
Sum of the quieſcent -	590	Sum of the divellent powers	605

So alſo if, inſtead of a ſolution of tartar vitriolate, that of GLAUBER's ſalt, or of vitriolic-ammoniac, or ſelenite, Epſom, or allum, be uſed; for in all theſe caſes the balance is conſtantly in favour of the divellent powers, yet the ſolutions of ſelenite and allum produce but a ſlight precipitation.

I alſo found, that the ſolution of ſilver is precipitated by the vitriolic ſolutions of iron, copper, tin, and probably by many other vitriolic ſolutions, if for no other reaſon at leaſt for this, that they conſtantly contain an exceſs of acid; but if a ſaturate ſolution of ſilver be mixed with a very ſaturate ſolution of lead or mercury in the vitriolic acid, the ſilver will not be precipitated, as I have obſerved; and in both caſes the balance is in favour of the quieſcent affinities.

The nitrous ſolution of ſilver is alſo decompoſed, and the ſilver precipitated by all *marino* neutral ſalts, whether the baſis be alkaline, terrene, or metallic, as I have experienced, and theſe decompoſitions are conſtantly indicated by the balance of affinities exhibited as above.

In the ſame manner ſilver is precipitated from the *vitriolic* acid by *marino* neutral ſalts, whether their baſis be alkaline, terrene, or metallic, as I have found on trial, and as the balance of affinities requires.

The nitrous ſolution of lead is alſo decompoſed, and the lead for the moſt part precipitated (unleſs the ſolution be very dilute) in the form of vitriol of lead by all the *vitriolico* neutral ſalts; and alſo by all the *marino* neutral ſalts, except marine ſalt of ſilver, which only precipitates it by virtue of its exceſs of acid.

The marine ſolution of lead is decompoſed by all *vitriolico* neutral ſalts, except ſelenite and vitriol of nickel, which can only precipitate it by virtue of an exceſs of acid.

The nitrous ſolution of mercury is alſo decompoſed, and the mercury for the moſt precipitated in the form of vitriol of mercury by all vitriolic neutral ſalts, except vitriol of lead, which can only decompoſe it by an exceſs of acid.

Nitrous ſolution of mercury is alſo decompoſed by *marino* neutral ſalts, except the marine ſalt of ſilver and lead, which can only affect it by an exceſs of acid.

Vitriol of mercury is alſo decompoſed by marino neutral ſalts, which decompoſition is alſo apparent by expoſing the antagoniſt powers; yet a precipitation does not always appear as I have remarked, particularly when marine allum is uſed, which I attribute to the facility with which a ſmall quantity of the marine ſalt of mercury is ſoluble in an exceſs of acid. Marine ſalt of ſilver decompoſes vitriol of mercury, only through its exceſs of acid.

Hence

Hence we ſee why horn ſilver can never be reduced by fixed alkalies without loſs, as Mr. MARGRAAF has ſhewn, I MARGR. 277.; nor could it be decompoſed at all, but that the action of heat helps that of the alkali.

If to a ſolution of ſublimate corroſive oil of vitriol be added, a precipitation will appear; but, as Mr. BERGMAN well remarks, this does not proceed from a decompoſition, but from a ſubſtraction of the water neceſſary to keep the ſublimate diſſolved.

If to a ſolution of vitriol of iron ſome nitrous acid be added, it immediately becomes turbid, becauſe the nitrous acid dephlogiſticates the calx of iron too much, but the addition of more acid reſtores the tranſparency, as the dephlogiſticated calx is ſtill ſoluble by a greater quantity of acid. I omit a number of other curious phenomena, which are explicable on theſe principles.

I have aſſigned in the foregoing table two different affinities to the vitriolic acid with regard to wiſmuth, and alſo to the marine acid with regard to nickel and wiſmuth. The firſt ſhews that which theſe acids bear to thoſe metals, when dephlogiſticated only by ſolution in thoſe acids. The ſecond number, that which the acids bear to them when more dephlogiſticated, as they are, when diſſolved in the nitrous acid. On the other hand, all the acids have leſs affinity to the calces of iron, zinc, tin, and antimony, when they are dephlogiſticated to a certain degree; but as I could give no criterion of this dephlogiſtication, I did not attempt to indicate the diminution it cauſes in the affinities of acids.

Of the precipitation of metals by each other from the mineral acids.

I am now come to the laſt point of my inquiry, and the moſt difficult to be ſet forth with that degree of preciſion which I have been enabled to attain in the former parts; for, in the firſt place, it is neceſſary to find the quantity of phlogiſton in each of them, not only in general, but according to their various degrees of dephlogiſtication by each of the acids. In this laſt particular I cannot aſſert that I have attained any thing like a certainty, yet I hope what I advance may not be uſeleſs to chymical readers, as it is not altogether groundleſs, as it contradicts no chymical fact, but, on the contrary, is agreeable to many, and affords a ready ſolution of all the phenomena.

Of the abſolute quantity of phlogiſton in metals.

The proportion of phlogiſton in metallic ſubſtances relatively to each other has been inveſtigated in ſo maſterly a manner by Mr. BERGMAN, that I lay it down as the ground of my inquiries. After his diſcovery all that remained was to find the abſolute quantity of it in any one metal, for then, by an eaſy calculation, it may be determined in all the reſt. The ſubſtance I choſe for this purpoſe was regulus of arſenic, as being moſt capable of dephlogiſtication by nitrous acid, though not altogether ſo.

From 100 grs. of regulus of arſenic, diſſolved in dilute nitrous acid, as already ſeen, 102 cubic inches of nitrous air and $\frac{4}{10}$ths are obtained, barometer at 30°, thermometer at 60°. I muſt add, that I made the experiment on 5 grs. only, ſo that the calculation relates only to the quantity of air which 100 grs. *ſhould* give. I repeated the experiment three times with the ſame ſucceſs. I attempted getting more air from the reſiduum left by a gentle evaporation, but though freſh ſpirit of nitre grew red with it, the quantity of air was quite inconſiderable.

Now this quantity of nitrous air contains 6,86 grs. of phlogiſton, according to the calculation to be ſeen in my former paper; and hence I conclude, that 100 grs. of regulus of arſenic contains 6,86 grs. of phlogiſton. This regulus was made by Mr. WOLFE, and perfectly bright.

Hence the relative proportion of phlogiſton in metals being, as found by Mr. BERGMAN, and ſet forth in the firſt column of the following table, the abſolute quantity will be as ſhewn in the ſecond column.

	Relative quantity of phlogiſton.	Abſolute quantity.
100 grs. Gold	394	24,82
Copper	312	19,65
Cobalt	270	17,01
Iron	233	14,67
Zinc	182	11,46
Nickel	156	9,82
Regulus of antimony	120	7,56
Tin	114	7,18
Regulus of arſenic	109	6,86
Silver	100	6,30
Mercury	74	4,56
Wiſmuth	57	3,59
Lead	43	2,70

This point being, as I conceived, of ſome importance, I endeavoured to aſcertain it ſtill further by other experiments: and as ſilver loſes a certain quantity of phlogiſton, which eſcapes and ſeparates from it during its ſolution in nitrous acid, I conceived, that if the ſolution was expoſed to nothing from which it could re-obtain phlogiſton, and thus diſtilled to dryneſs, and intirely ſeparated from the acid, as much ſilver ſhould remain unreduced as correſponded with the quantity of phlogiſton loſt by it. And if this quantity of phlogiſton correſponded with that aſſigned to ſilver in the foregoing table, that then this table was juſt.

For this purpoſe I diſſolved 120 grs. of clean filings of ſtandard ſilver in dilute dephlogiſticated nitrous acid, and obtained from it 24 cubic inches of nitrous air. This ſolution I gently evaporated to dryneſs; by the evaporation I found a little of the ſilver volatilized, but not more than a quarter of a grain. I then diſtilled the dry reſiduum, and kept it an hour in almoſt a white heat in a coated green glaſs retort. During the diſtillation abundance of the nitrous acid paſſed off, a green and white ſublimate aroſe in the neck of the retort, and ſome paſſed even into the receiver. When all was cold I broke the retort, the inſide of which was penetrated into its very ſubſtance with a yellow and red tinge, and partly covered over with an exceeding fine ſilver powder, which could ſcarcely be ſcraped off. The remainder of the ſilver was perfectly white and free from acid, but not melted into a button, and when collected weighed 94 grs.; therefore 26 grs. were loſt, that is, were ſublimed or vitrified; but of theſe 26 grs. 9 grs. were copper (for 100 grs. ſtandard ſilver contain 7½ of copper); therefore, only 17 grs. of pure ſilver remained unreduced, being either volatilized or vitrified. The whole quantity of pure ſilver in 120 grs. of ſtandard ſilver amounts to 111 grs.; then if 111 grs. of pure ſilver loſe 17 by reaſon of its loſs of phlogiſton, 100 grs. of pure ſilver ſhould loſe 15,3; and by the above table 15,3 grs. of ſilver ſhould contain 0,945 of a grain of phlogiſton. Let us now ſee whether this quantity of phlogiſton correſponds with that which 100 grs. of pure ſilver really loſe by ſolution in nitrous acid. 100 grs. of pure ſilver afford, as already ſaid, 14 cubic inches of nitrous air, which, by my computation, contain 0,938 of a grain of phlogiſton, which differs from 0,945 only by $\frac{7}{1000}$. The unreduced part of the ſilver was 15,3 grs.; and, by calculating what it ſhould be by reaſon of the loſs of the phlogiſton contained in the nitrous air, it would amount to 14 and $\frac{9}{10}$ths of a grain, a difference certainly immaterial.

In this experiment, only as much of the ſilver ſublimed as could not regain phlogiſton; the remainder regained it from the nitrous air abſorbed by the ſolution, and alſo from that which remained united to the acid and calx. If this were not ſo, I do not ſee why the whole of the ſilver would not ſublime.

Again: Dr. PRIESTLEY having ſeveral times diſſolved mercury in the nitrous acid, and revivified it by diſtilling over that acid, conſtantly found a conſiderable proportion of it unreduced. To try whether that proportion correſponded with my calculation, I have examined the experiment which he made with moſt care, and which is to be found in his 4th vol. p. 262. We there find, that having diſſolved 17 dwts 13 grs. = 321 grs. of mercury in nitrous acid, 1½ dwt. that is, 36 grs. remained unreduced. Now, according to my calculation, 56 grs. ſhould remain unreduced; for 100 grs. of mercury afford 12 cubic inches of nitrous air; therefore 321 grs. ſhould afford 38,52, which contain 2,58 grs. of phlogiſton, and if (according to the table) 4,56 grs. of phlogiſton be neceſſary to metallize 100 grs. of mercury, 2,58 will be neceſſary to metallize 56 grs.

of mercury: and I am ſatisfied, from my own trials, that more than 50 grs. would be found unreduced if dephlogiſticated nitrous acid had been uſed in diſſolving the mercury, and the ſolution performed with heat and a ſtrong acid; but that which Dr. PRIESTLEY uſed, being the red or yellow ſort, already contained much phlogiſton, which contributed to the revivification of a larger quantity of mercury than would otherwiſe be found. It is true, that Dr. PRIESTLEY afterwards revivified a great part of what originally remained unreduced; but this happened after it was for ſome time expoſed to the free air, from which the calces of the perfect metals always attract phlogiſton, as is evident in luna cornua, which blackens on expoſure to the air, and hence alſo proceed the reductions operated by Mr. BAYEN.

But Dr. PRIESTLEY, to whoſe luminous experiments chymiſtry is already ſo much indebted, has been ſo obliging as to furniſh me with ſome which tend more directly to elucidate the preſent queſtion.

In one experiment he found that nearly 5 dwts. of minium, from whence all its air was extracted, that is, about 118 grs. abſorbed 40 oz. meaſures of inflammable, that is, 75,8 cubic inches = 2,65 grs. of phlogiſton, and were then reduced: then 100 grs. of minium ſhould require for their reduction nearly 2,25 grs. of phlogiſton. In another experiment, made with more care, he found, that 480 grs. of minium abſorbed 108 oz. meaſures of inflammable air; according to this then 100 grs. of minium require for their reduction 1,49 grs. of phlogiſton; and in two other experiments he found this quantity ſtill leſs. Upon which I remark, firſt, that the whole of the minium was not dephlogiſticated; for, beſides that it is never throughout equally calcined, much of it muſt have been reduced during the expulſion of its air; ſecondly, that the quantity of the phlogiſton in the inflammable air may have been greater as this varies with its temperature, and the weight of the atmoſphere; ſo that upon the whole theſe experiments confirm the reſults expreſſed in the table.

Of the affinity of metallic calces to phlogiſton.

That inflammable air or phlogiſton is condenſed to a very conſiderable degree by uniting to any metallic ſubſtance, ſo that its ſpecific gravity is not only equal, but much ſuperior, to that of the metallic earth with which it combines, may eaſily be concluded from the example of fixed air, which, by uniting to calcareous earth, acquires a ſpecific gravity equal to that of gold; and hence, that metallic earth which condenſes phlogiſton moſt, and in greateſt quantity, uniting to it moſt cloſely, may be ſaid to have the greateſt affinity to it; ſo that if we could find the ſpecific gravity of a calx perfectly pure, both from phlogiſton and fixed air, we could, by comparing its denſity with that of the ſame calx when metallized, know the denſity which phlogiſton acquires by its union with ſuch calx; but to procure ſuch calces hath hitherto proved impoſſible, as, during their dephlogiſtication, they combine with fixed air, or ſome particles of their menſtruum; and hence their abſolute weight is increaſed, though their ſpecific gravity be ſomewhat diminiſhed. From this laſt circumſtance it appears, that the ſpecific gravity of calces differs much leſs from that of their reſpective metals than does the ſpecific gravity which the phlogiſton acquires by its union with thoſe calces, from that which it poſſeſſes in its uncombined ſtate; in the ſame manner as the denſity of quick-lime differs much leſs from that of limeſtone, than does the denſity which fixed air acquires by its union with quick-lime from that which belongs to it in its aërial ſtate; and hence, inſtead of deducing the quantity of affinity of metallic calces to phlogiſton from the following propoſition, *viz.* that *the affinity of metallic calces to phlogiſton is in a compound ratio of its quantity and denſity in each metal,* I am obliged to deduce it from this other, *viz.* that *the affinity of metallic calces to phlogiſton is directly as the ſpecific gravity of the reſpective metals, and inverſely as the quantity of calx contained in a given weight of thoſe metals.* This latter propoſition is an approximation to the former, founded on this truth, that *the larger the quantity of phlogiſton in any metal is, the ſmaller is the quantity of calx in a given weight of that metal*; and that *the denſity which the phlogiſton acquires, is as the ſpecific gravity of the metal.* This latter propoſition, however, is not exactly true, for this denſity is much greater; yet it is the neareſt approximation I can make, and its defect is ſenſible only with regard to thoſe metals which contain a conſiderable quantity of phlogiſton, *viz.* gold, copper, cobalt, and iron: with regard to the reſt it is of no importance.

Then the ſpecific gravity of metals being as repreſented in the firſt column of the following table, the affinity of their calces to phlogiſton will be as is ſhewn in the ſecond column. The third column expreſſes theſe affinities in numbers homogenous with thoſe which expreſs the affinities of acids with their baſis.

	Specific gravity.		Affinity of the calces to phlogiſton.
Gold	19	0,25	1041
Mercury	14	0,147	612
Silver	11,091	0,118	491
Lead	11,33	0,116	483
Copper	8,8	0,109	454
Wiſmuth	9,6	0,099	412
Cobalt	7,7	0,092	383
Iron	7,7	0,090	375
Regulus of arſenic	8,31	0,089	370
Zinc	7,24	0,0817	340
Nickel	7,33	0,0812	338
Tin	7,	0,075	312
Regulus of antimony	6,86	0,074	308

Here we ſee, that the calx of lead has a greater affinity to phlogiſton than the calces of any of the imperfect metals, and hence its uſe in cuppellation; for after it has loſt its own phlogiſton, it extracts that of the baſe metals, and thus promotes their calcination and vitrification.

Though the numbers in the ſecond column expreſs tolerably well the greater or leſſer affinity of metallic calces to phlogiſton, yet they have this inconvenience, that they are not homogenous with thoſe that expreſs the affinities of acids to other baſes, which limits their uſe to a narrow compaſs, they being, on that account, incomparable with thoſe that expreſs the affinities of acids: I therefore endeavoured to find a coincidence between them in ſome one inſtance, in order to reduce them to the ſame ſtandard, as will be ſeen in the next paragraph.

Of the affinity of the vitriolic acid to phlogiſton in ſulphur.

According to the principle above laid down, this affinity is in a compound ratio of the quantity of phlogiſton taken up by 100 grs. of the vitriolic acid and of the denſity it acquires by its union with the acid. Now 100 grs. of ſulphur contain 59 of acid and 41 of phlogiſton, and the ſpecific gravity of ſulphur is 2,344; therefore, the loſs of weight of ſulphur in water = $\frac{100}{2{,}344} = 42{,}66$ grs. the loſs of weight of the acid part of the ſulphur is $\frac{59}{4{,}226} = 13{,}96$ grs.; therefore, the remainder of the loſs of ſulphur is the loſs of the phlogiſtic part = 28,70 grs.; then the abſolute weight of the phlogiſton being 41 grs. its denſity will be $1{,}429 = \frac{41}{28{,}7}$; and ſince 100 grs. of vitriolic acid take up 70 of phlogiſton its affinity will be 1,429 × 70 = 100. But if the affinity of the vitriolic acid to phlogiſton in ſulphur had been ſought in the ſame manner with the affinity of metallic calces to phlogiſton, the quantity would be the ſame, though the expreſſion of that quantity would be different, as relating to a different ſtandard; for by that method the affinity would be directly as the denſity of the phlogiſton, and inverſely as the quantity of vitriolic acid contained in 100 grs. of ſulphur, that is, $\frac{1{,}429}{59} = {,}024$; therefore, this expreſſion anſwers to, and is equivalent to the former, *viz.* 100. By this means I formed the quantities expreſſed in the third column, which are homogenous to thoſe which expreſs the affinities of acids to their baſis. Thus, the affinity of the calx of gold to phlogiſton is 1041, for :: ,024 . 100 :: ,25 . 1041, &c.

The third point neceſſary for the explanation of the phenomena attending the ſolution of metals, and their precipitation by each other, is to determine the proportion of phlogiſton which they loſe by ſolution in each of the acids, and the affinity which their calces bear to the part ſo loſt. I have not been able to determine this by any direct experiment; for though I might determine the part which eſcapes in the form of air, yet I could not that which is equally ſeparated from the metal, but retained in the ſolution; yet from various collateral conſiderations I am induced to think, the proportion of phlogiſton, ſeparated from the metals by the different acids, is, at a medium, as expreſſed in the following table.

	Iron.	Copper.	Tin.	Lead.	Silver.	Mercury.	Zinc.	Wiſmuth.	Cobalt.	Nickel	Reg. of antimo.	Reg. of arſenic.
By vitriolic acid	$\frac{2}{3}$	$\frac{8}{10}$	$\frac{7}{10}$	$\frac{98}{100}$	Intire	$\frac{87}{100}$	$\frac{85}{100}$	$\frac{85}{100}$	$\frac{93}{100}$	Intire	$\frac{97}{100}$	$\frac{86}{100}$
By nitrous acid	$\frac{2}{3}$	$\frac{81}{100}$	$\frac{7}{10}$	$\frac{88}{100}$	Intire	$\frac{9}{10}$	$\frac{99}{100}$	$\frac{97}{100}$	Intire	Intire	Intire	$\frac{99}{100}$
By marine acid	$\frac{42}{100}$	$\frac{57}{100}$	$\frac{3}{10}$	$\frac{6}{10}$			$\frac{6}{10}$	$\frac{7}{10}$	$\frac{94}{100}$	$\frac{8}{10}$	$\frac{84}{100}$	$\frac{8}{10}$

On this ſuppoſition the affinity of the calces to the deficient part of their phlogiſton may eaſily be calculated; for they may be conſidered as acids whoſe affinity to the deficient part of their baſis is as the ratio which that part bears to the whole, as already ſaid. Thus the affinity of iron, thoroughly deprived of its phlogiſton, being 375, as it loſes $\frac{2}{3}$ds of its phlogiſton by ſolution in the vitriolic acid, the affinity of iron to theſe two-thirds is $\frac{2}{3}$ds of its whole affinity, that is, $\frac{2}{3}$ds of 375 = 250.

Theſe affinities, together with thoſe of the three acids to the ſeveral calces, are repreſented together in the following table.

Vitriolic

	Iron.	Copper.	Tin.	Lead.	Silver	Mercury.	Zinc.	Wiſmuth.	Cobalt.	Nickel.	Reg. of antimo.	Reg. of arſenic.
Vitriolic acid	270	260	138	412	390	432	318	250.310	360	320	200	260
Calx to phlog.	250	360	218	483	491	532	298	350	300	338	300	320
Nitrous acid	255	255	120	363	375	416	304	290	350	300	194	255
Calx to phlog.	250	363	218	424	491	552	337	400	383	338	308	366
Marine acid	265	265	130	400	420	438	312	250.320	370	275.310	198	290
Calx to phlog.	165	260	104	290	491	500	200	280	360	265	240	300

The affinities of calces to phlogiſton are taken at a medium; for almoſt all metallic ſubſtances are capable of greater or leſſer dephlogiſtication, according to the ſpecies, concentration, and dephlogiſtication of their menſtruum. The more they are dephlogiſticated, the greater their affinity to phlogiſton; and, in general, the leſs their affinity to the mineral acids. Yet there is a point of dephlogiſtication at which the attraction of acids to the calces is ſtrongeſt: thus the vitriolic acid attracts biſmuth moſt ſtrongly after it has been dephlogiſticated by the nitrous acid; and the marine acid attracts both biſmuth and nickel more powerfully, when dephlogiſticated by the nitrous or vitriolic acids.

From theſe *data* we may eaſily conceive, in moſt caſes, what will happen on putting one metal into the ſolution of another.

Thus, if a piece of copper be put into a ſaturate ſolution of ſilver, the ſilver will be precipitated; for the balance is in favour of the divellent powers.

Quieſcent affinities.		Divellent affinities.	
Nitrous acid to ſilver -	375	Nitrous acid to copper -	255
Calx of copper to phlogiſton	363	Calx of ſilver to phlogiſton	491
Sum of the quieſcent affinities	738	Sum of the divellent —	746

The ſolutions muſt be nearly ſaturate, elſe a large quantity of the added metal will be diſſolved by the free acid, before any precipitation can appear; yet it muſt not be intirely ſaturate, at leaſt in ſome caſes, as will preſently be ſeen.

I ſaid in *moſt caſes*, becauſe in ſome, particularly where mercury, biſmuth, cobalt, regulus of antimony or arſenic, are uſed, another power intervenes which has not yet been fully inveſtigated, *viz.* the attraction of calces to each other, which I ſhall occaſionally mention.

It is worthy of obſervation, that the precipitating metals are more dephlogiſticated by this means than by direct ſolution in their reſpective menſtruums, and are even diſſolved by menſtruums that would not otherwiſe affect them; becauſe their phlogiſton is torn from them by two powers inſtead of one: thus, though copper be directly ſoluble in the vitriolic acid, only when this acid is concentrated and heated to a great degree, yet if a piece of copper be put into a dilute cold ſolution of ſilver or mercury in the vitriolic of acid, or even into a dilute ſolution of iron, expoſed to the open air, it will be diſſolved; a circumſtance which juſtly excited the wonder of Mr. MARGRAAF and Mr. WENZEL, who did not apprehend the theory of it: and hence we ſee how vitriol of copper may be formed by nature, and why it always contains a mixture of iron.

Of ſolutions in the vitriolic acid.

This acid diſſolves iron and zinc, without the aſſiſtance of heat; becauſe its affinity to their calces is greater than the affinity

nity which theſe calces bear to that portion of phlogiſton which they muſt loſe before they can unite to the acid, as may be ſeen by inſpecting the table; but all other metallic ſubſtances unite to this acid only where it is concentrated and heated.

Of ſolutions in the nitrous acid.

The nitrous acid has leſs affinity to all metallic ſubſtances than either the vitriolic or marine. It has alſo leſs affinity to them than they have to that portion of phlogiſton which they muſt loſe before they can unite to it; yet it diſſolves them all (gold and platina excepted) even without the aid of heat becauſe it unites itſelf to phlogiſton unleſs too dilute; and the heat produced by its union with phlogiſton is ſufficient to promote the ſolution.

But if it be too concentrated, it will not act either on lead or ſilver, without the aſſiſtance of heat, as BOYLE and BOERHAAVE have remarked[*]; for the difference betwixt its affinity to theſe metals, and that of theſe metals to the portion of phlogiſton which they muſt loſe before they can unite to it, is very great; and when it is very concentrated, the liquor does not contain fire enough to throw the phlogiſton and it into an aërial form, and reduce the ſolid to a liquid; the ſame would probably be obſerved with regard to mercury, if it had not been already in a liquid ſtate. STAHL has alſo remarked, that it produces very little heat in diſſolving ſilver, and none in diſſolving lead or mercury[†]. This is eaſily explained, now that we know that ſilver contains but little phlogiſton, and lead much leſs, the heat being evidently produced, according to the law diſcovered by Dr. CRAWFORD, by the union of phlogiſton to the acid, for metallic calces produce no heat. As to mercury, the obſervation is not exact, for its ſolution is accompanied with heat, as Mr. LAVOISIER has obſerved, 1 LAVOIS. 248.

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[*] 1 SHAW's BOERH. 508. 2 SHAW's BOYLE 335.

[†] STAHL ſur les ſels 168.

Of ſolutions in the marine acid.

This acid is known to dephlogiſticate metals leſs than any other. Where the portion of phlogiſton, neceſſary to be ſeparated, is more ſtrongly attracted than the acid itſelf, it can operate no ſolution, or at leaſt very ſlowly, without the aid of heat; nor even where the attraction of acid is ſtronger to the calx than that of the portion of phlogiſton it ſeparates, if the proportion of acid to ſuch calx be very ſmall; becauſe ſo ſmall a quantity of acid does not contain fire enough to volatilize the phlogiſton; and hence heat is neceſſary for the ſolution of lead in this acid. The dephlogiſticated acid acts more powerfully.

Of precipitations of and by iron.

The mutual precipitations of iron and copper from the vitriolic acid by each other, have been well explained in a general manner by Mr. MONNET and Mr. BERGMAN; I ſhall here ſhew the reaſon of theſe precipitations more diſtinctly.

If a piece of copper be put into a ſaturate ſolution of iron, freſh made, no precipitation will happen, nor will any of the copper be diſſolved in twelve hours, nor even in a longer time, if the acceſs of air to the ſolution be prevented; but if the ſolution be expoſed to the open air, the addition of a volatile alkali will ſhew the copper to have been acted upon in 24 hours, or ſooner if heat be applied, and a calx of iron is precipitated. The operation of the affinities in the firſt caſe is as follows.

Quieſcent.		Divellent.	
Vitriolic acid to calx of iron	270	Vitriolic acid to copper	260
Copper to its phlogiſton	360	Calx of iron to phlogiſton	250
Sum	630	Sum	510

Hence, in this caſe, no decompoſition can happen; but in the ſecond caſe, much of the phlogiſton of the ſolution of iron having eſcaped, the affinity of the calx of iron to acid is diminiſhed, and that to phlogiſton is increaſed, and therefore the quieſcent affinities may be ſuppoſed,

		and the divellent.	
Vitriolic acid to the calx of iron	240	Vitriolic acid to copper	260
Copper to its phlogiſton	360	Calx of iron to phlogiſton	370
	600		630

But from the increaſed affinity of the calx of iron to phlogiſton it might be inferred, that as the iron recovers its phlogiſton, the acid ſhould re-act upon it and quit the copper; and this would certainly happen, if it recovered its phlogiſton in ſufficient quantity, but the acceſs of air and heat prevents its retaining it, at leaſt in ſufficient quantity.

This increaſed affinity of the calx of iron to phlogiſton is not a mere ſuppoſition; for, if into a ſolution of iron, ſo far dephlogiſticated as to refuſe to cryſtallize, ſome freſh iron be put, the impoveriſhed calx will re-attract ſo much of the phlogiſton given out during the ſolution of the freſh iron, that it will now afford cryſtals, as Mr. MONNET has obſerved in his excellent Treatiſe on Vitriolization. The diminiſhed attraction of the calx of iron to acids is alſo evident from this experiment, and alſo from the neceſſity of adding more acid to a turbid ſolution of iron, in order to re-eſtabliſh its tranſparency. The calces of copper alſo precipitate a dephlogiſticated ſolution of iron, as they ſhould, the affinity of the acid to ſuch calx of iron being 240, and that to copper being 260. With regard to the ſolution of iron in nitrous acid, the ſame thing happens; but as this ſolution contains a large exceſs of acid, a portion of copper is diſſolved even before any of the iron is precipitated.

With regard to a ſolution of iron in the marine acid, though expoſed to the open air, copper precipitates nothing from it in 24 hours.

But if a clean piece of iron be put into a ſolution of copper in the vitriolic acid, the copper is immediately precipitated; for here the quieſcent and divellent affinities exhibited in the firſt ſcheme are reverſed, the quieſcent becoming the divellent, and *vice verſâ*. It is needleſs to add, that copper is in the ſame manner precipitated by iron from the nitrous and marine acids.

Hence the practice of extracting copper from ſome mineral waters by means of iron. Theſe waters, therefore, furniſh afterwards, by evaporation, vitriol of iron; but it is remarkable, that this vitriol is much paler than the common, and leſs fit for dying, 2 SCHLUTTER 507. The reaſon of which is, that it is more dephlogiſticated, not only becauſe old iron is chiefly uſed, but becauſe copper, containing more phlogiſton than an equal weight of iron, deprives it of more of its phlogiſton than it would loſe if barely diſſolved in the vitriolic acid.

Caſt iron, according to SCHLUTTER, will ſcarcely precipitate a ſolution of copper; and in effect Mr. BERGMAN has found that it contains leſs phlogiſton than bar iron.

I have always found ſilver to be eaſily precipitated from its ſolution in the nitrous acid by iron. The ſum of the quieſcent affinities being 625, and that of the divellent 746; yet Mr. BERGMAN obſerved, that a very ſaturate ſolution of ſilver was very difficultly precipitated, and only by ſome ſorts of iron, even though the ſolution was diluted, and an exceſs of acid added to it*; the reaſon of this curious phenomenon appears to me deducible from a circumſtance firſt obſerved by Mr. SCHEELE, in diſſolving mercury, namely, that the nitrous acid, when ſaturated with it, will take up more of it in its metallic form†. The ſame thing happens in diſſolving ſilver in the nitrous acid in a ſtrong heat; for, as I before remarked, the laſt portions of ſilver thrown in afford no air, and conſequently are not dephlogiſticated. Now this compound of calx of ſilver, and ſilver in its metallic form, may well be unprecipitable by iron, the ſilver, in its metallic form, preventing the calx from coming in contact with the iron, and extracting phlogiſton from it: and hence alſo, iron has ſometimes been obſerved not to precipitate a ſolution of mercury in this acid‡.

It has been long thought, that iron may be precipitated from acids by zinc, though NEWMAN long ago denied it; but Mr. BERGMAN has ſatisfactorily cleared up this point, by ſhewing that zinc cannot precipitate iron from the vitriolic acid, until the ſolution of iron loſes part of its phlogiſton. With regard to the nitrous acid, I found, that zinc does not precipitate iron; but, on the contrary, iron precipitates zinc; but in a ſhort time the acid re-diſſolves the zinc, and lets fall the iron, which evidently proceeds from the too great dephlogiſtication of the calx of iron. But zinc precipitates iron from the marine, though with difficulty; for after 24 hours the galls ſtill ſtruck a black. I ſhould alſo add, that iron does not precipitate zinc from the vitriolic acid.

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* Diſſert. de Phlog. Quantitate in Metal. p. 6.

† 39 SUENSK. Handling, p. 70.

‡ 2 CRELL. Nev. Entdeck. p. 266.

Moſt metallic ſubſtances, precipitated by iron from the nitrous acid, are in ſome meaſure re-diſſolved ſhortly after, as the nitrous acid ſoon dephlogiſticates the iron too much, then lets it fall, and re-acts on the other metals and re-diſſolves them.

The precipitation of the argillaceous earth from allum by iron is owing to the exceſs of acid in the allum which firſt dephlogiſticates the iron; and when this is dephlogiſticated, it attracts the acid more ſtrongly. Earth of allum, on the other hand, precipitates iron when the ſolution of iron is dephlogiſticated by heat. It may alſo produce this effect by depriving iron of its exceſs of acid which keeps it in ſolution.

Of precipitations of and by copper.

When ſilver is diſſolved in the nitrous acid, and a piece of copper is put into the ſolution, it ſometimes happens, that the ſilver is not precipitated, as Dr. LEWIS has obſerved [*]. This happens either when the nitrous acid is ſuperſaturated with ſilver having taken up ſome in its metallic form, as already obſerved; or when the ſilver is not much dephlogiſticated, for then its affinity to phlogiſton, which is the principal cauſe of its precipitation, is leſs than 491; therefore, the remedy is to heat it and add more acid, by which it is dephlogiſticated further. However, the nitrous acid always retains a little ſilver. SCHLUTTER. 362. Hiſt. Mem. Par. 1728.

It is commonly ſaid, that if filings of copper be put into a boiling ſolution of allum, vitriol of copper will be found, and the earth of allum precipitated. If this were true it would be very ſurpriſing, as copper is ſoluble, even with the aſſiſtance of heat, only in the concentrated vitriolic acid. Hence I made the experiment, and found, that after 20 hours boiling not the ſmalleſt particle of copper was diſſolved, for the colour of the ſolution was not altered by volatile alkalies: and though the allum was precipitated, it ſtill retained its ſaline form, ſo that it loſt only its exceſs of acid in this experiment.

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[*] Commercium Philoſ. p. 157.

Of precipitations of and by tin.

Tin is not precipitated, in its metallic form, by any metallic ſubſtance; and the reaſon is, becauſe its precipitation is not the effect of a double affinity, but of the ſingle greater affinity of its menſtruum to every other metallic earth. Metals that are precipitated from the nitrous acid by tin, are afterwards rediſſolved, becauſe the acid ſoon quits the tin, it becoming too much dephlogiſticated.

Of precipitations of and by lead.

Metals diſſolved in the vitriolic and marine acids, and precipitable by lead, according to the indication of the balance of affinities, are yet ſlowly precipitated, becauſe the firſt portions of lead that are diſſolved form ſalts of difficult ſolution, which cover its ſurface, and protect it from the further action of the acid; and yet it contains ſo little phlogiſton, that a great deal of it muſt be diſſolved before it gives out enough to precipitate the diſſolved metals.

Mr. BERGMAN obſerved, that a very ſaturate ſolution of lead is difficultly, if at all, precipitable by iron. Does not this alſo ariſe from ſome lead being taken up in its metallic form? Iron does not precipitate lead from the marine acid, though a precipitate appears; for this precipitate ſtill retains the marine acid: on the contrary, lead precipitates iron from this acid, though very ſlowly.

Of precipitations of and by mercury.

Though the difference betwixt the quieſcent and divellent powers be very ſmall, yet mercury is quickly precipitated from the vitriolic acid by copper; becauſe the attraction of the calx of mercury to phlogiſton is very ſtrong, and a very ſmall proportion of that contained in copper is ſufficient to revive it.

Silver does not precipitate mercury from the vitriolic acid, unleſs it contains copper, and then it does precipitate it; yet if ſilver and turpeth mineral be diſtilled, the mercury will paſs in its metallic form, WENZEL 42.; which ſhews that the affinity of calx of mercury to phlogiſton is increaſed by heat. The difference betwixt the quieſcent and divellent powers is indeed very ſmall.

Silver appeared to me to precipitate mercury from the nitrous acid, though very ſlowly, when the ſolution of mercury was made with heat, and not over ſaturated; but when the ſolution of mercury was made without heat, it was not at all precipitated. On the other hand, mercury precipitates ſilver from this acid, not by virtue of the ſuperiority of the uſual divellent powers, but by reaſon of the attraction of mercury and ſilver to each other, for they form partly an amalgama and partly vegetate, and ſcarce any of either remains in the ſolution. The ſame thing happens, that is, they vegetate, if ſolutions of both metals in the ſame acid be mixed together.

Silver does not precipitate mercury from the ſolution of ſublimate corroſive; but, on the contrary, mercury precipitates ſilver from the marine acid: and if a ſolution of horn ſilver in volatile alkali be triturated with mercury, the ſilver will be freed from its acid and calomel formed, 1 MARGRAAF 284.; and yet, if calomel and ſilver be diſtilled, the mercury will paſs in its metallic form, and horn ſilver will be formed, *ibid.* 286. The ſame thing happens if ſilver and ſublimate corroſive be diſtilled, 1 POTT. 338. STAHL *des ſels*, 306; the affinity of calx of mercury to phlogiſton increaſing with the heat.

Of precipitations of and by biſmuth.

With reſpect to the vitriolic acid I have made the ſum of the quieſcent and divellent powers equal, though in fact ſometimes the one preponderates and ſometimes the other. Wiſmuth precipitates nothing from vitriol of copper in 16 hours; nor does copper from vitriol of wiſmuth. Copper is ſaid to precipitate wiſmuth from the nitrous acid; but I have alſo ſeen copper precipitated from this in its metallic form by wiſmuth. The variations proceed from the different dephlogiſtication of copper.

Of precipitations of and by nickel.

Unleſs nickel be pulveriſed it ſcarcely precipitates any metal.

Zinc precipitates a black powder from the ſolution of nickel in the vitriolic and nitrous acid, which Mr. BERGMAN, by a method peculiar to him, has ſhewn to conſiſt of arſenic, nickel, and a little of the zinc itſelf. The arſenic attracting the calx of nickel *; but zinc precipitates nickel from the marine acid.

The ſolution of iron in vitriolic acid acts on nickel, and that of nickel in this ſame acid acts on iron; but neither precipitates the other in 24 hours; but on longer reſt, iron ſeems to have the advantage; but iron clearly precipitates nickel from the nitrous acid; and though nickel ſeems alſo to precipitate iron, yet this ariſes only from the gradual dephlogiſtication of the iron.

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* 1 SUENSK. Handling. 1780.

Nickel precipitates copper in its metallic form from the vitriolic acid. It alſo precipitates copper from the nitrous and marine acids; but copper precipitates arſenic from a nitrous ſolution of nickel. The vitriolic and nitrous ſolutions of lead ſeem to act in ſpecie on nickel, that is, to diſſolve it without any decompoſition, the calces uniting to each other. The vitriolic and nitrous ſolutions of nickel for ſome time act on lead in the ſame manner; but at laſt nickel ſeems to have the advantage. With regard to the marine acid, lead ſeems to have the advantage, though a black precipitate is ſeen, whichever of them is put into the ſolution of the other.

Nickel readily precipitates wiſmuth from the vitriolic and nitrous acids; but as to the marine I found each of theſe ſemimetals ſoluble in the ſolution of the other, yet nickel precipitates wiſmuth very ſlowly, and only as to part; and wiſmuth precipitates a red powder, which I take to be ochre, from the ſolution of nickel.

Nickel and tin are ſlightly acted on, each by the ſalt of the other; but the precipitations are as indicated by the balance of affinities.

Of precipitations of and by cobalt.

Cobalt is not precipitated either from the vitriolic or nitrous acid by zinc; but it ſeemed to me to be precipitated by zinc from the marine acid.

Though iron precipitates cobalt from the three acids, yet I found much of the cobalt retained both by the vitriolic and nitrous acids, particularly the latter, which, after letting fall the cobalt, afterwards re-takes it, and lets fall the dephlogiſticated calx of iron.

Nickel alſo, though it does not precipitate cobalt itſelf, as appears by the remaining redneſs of the ſolution, yet conſtantly precipitates ſome other heterogenous ſubſtance from it. The ſolution of cobalt in the marine acid becomes colourleſs by the addition of nickel.

Wiſmuth is ſoluble in the vitriolic and nitrous ſolutions of cobalt, and cauſes a ſmall white precipitate, but does not affect the true cobaltic part. Theſe ſolutions in vitriolic acid cannot be attributed to an exceſs of acid, as they are made in a dilute acid, and without heat. Copper alſo precipitates a white ſubſtance from the nitrous ſolution of cobalt, which I take to be arſenic.

It is difficult to procure either nickel or cobalt very pure; it is evident thoſe I uſed were not ſo.

Of precipitations of and by regulus of antimony.

Copper neither precipitates, nor is precipitated from, the vitriolic acid by regulus of antimony, at leaſt in three days; but vitriol of antimony in ſpecie diſſolves it ſlowly.

The regulus is alſo acted upon by vitriol of lead, for it becomes red after remaining 16 hours in the ſolution of that vitriol; and lead ſcarcely precipitates it from the vitriolic acid.

I alſo found, that powdered regulus precipitates vitriol of mercury very ſlightly.

Wiſmuth neither precipitates, nor is precipitated by, this regulus from the vitriolic acid in 24 hours.

Though tin precipitates this regulus from the nitrous acid, yet if the regulus be put into a ſolution of tin in this acid, in 16 hours neither will be found in the ſolution, either by reaſon of the dephlogiſtication, or of the union of the calces to each other.

Iron does not precipitate this regulus intirely from the marine acid, but a triple ſalt ſeems to be formed, conſiſting of the acid and both calces. The regulus is alſo ſoluble in marine ſalt of iron.

Neither does copper precipitate the regulus from marine acid in 16 hours; and if the regulus be put into marine ſalt of copper it will be diſſolved, and volatile alkalies will not give a blue but a yellowiſh white precipitate, ſo that here alſo a triple ſalt is formed.

Of Precipitations of and by regulus of arſenic.

The ſolutions of arſenic act in moſt caſes like two acids: thus iron, copper, lead, nickel, and zinc, are acted on by vitriol of arſenic (that is, its ſolution in vitriolic acid) but ſcarce give any precipitate.

Neither does iron precipitate arſenic from the nitrous acid, but copper does, and even ſilver gives a ſlight white precipitate; but regulus of arſenic precipitates ſilver completely in 16 hours. Hence the former precipitate ſeems to be a triple ſalt.

Mercury alſo ſlightly precipitates arſenic from the nitrous acid, and ſeems to unite to it, yet is itſelf precipitated by regulus of arſenic in 24 hours.

Wiſmuth forms a ſlight precipitate in the nitrous ſolution of arſenic; but regulus of arſenic forms a copious precipitate in the nitrous ſolution of wiſmuth; ſo that I believe the calces unite.

Nickel does not precipitate arſenic from the nitrous acid, but both calces unite; but regulus of arſenic produces a copious precipitate in the nitrous ſolution of nickel, yet the liquor continues green ; ſo that certainly the nickel is not precipitated ; the white precipitate in this caſe ſeems to be ſlightly dephlogiſticated arſenic.

This regulus alſo cauſes a white precipitate in the nitrous ſolution of cobalt, but the liquor ſtill continues red.

With regard to the marine acid, copper precipitates the regulus, but volatile alkalies do not ſtrike a blue with this ſolution, which ſhews the copper unites with the arſenic. Iron alſo precipitates the arſenic. Tin is ſoluble in marine ſolution of arſenic, but I could obſerve no precipitate, nor does regulus of arſenic precipitate tin.

Neither wiſmuth nor the regulus of arſenic precipitate each other from the marine acid in 16 hours. Regulus of antimony is alſo acted upon by the marine ſolution of arſenic, though it cauſes no precipitate, nor does the regulus of arſenic precipitate it.